W. B. No. 443. Issued Dec. 31, 1910.

U. S. DEPARTMENT OF AGRICULTURE,

WEATHER BUREAU.

BULLETIN T.

FROST AND TEMPERATURE CONDITIONS IN THE CRANBERRY MARSHES OF WISCONSIN.

Prepared under the direction of WILLIS L. MOORE, Chief of Weather Bureau,

By

HENRY J. COX, Professor of Meteorology.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

f. e. H W MCM. Feb. 2, 1911.

CONTENTS

ILLUSTRATIONS.

ACKNOWLEDGMENTS.

The assistance of those who have taken part in this investigation is hereby acknowledged: Mr. R. N. Covert, United States Weather Bureau, performed work in the field at Mather in 1906 and prepared several of the drawings used in the publication; both Mr. G. M. Richards and Mr. E. H. Haines, United States Weather Bureau, carried on the field work at Mather during the season of 1907, and the latter also made the computations appearing in the tables. A vast amount of tabulated data has been prepared, although few of the tables have been published, as a whole, for want of space.

Acknowledgment is also made of courtesies extended by Mr. H. R. Laing, manager of the Stanley Marshes at Berlin, Wis.; Judge John Gaynor, Grand Rapids, Wis.; Prof. A. R. Whitson, of the University of Wisconsin; Mr. J. N. King, Mather, Wis.; the Federal Cranberry Company, South Carver, Mass.; and Mr. J. J. White, of New Lisbon, N. J.

Prof. W. J. Humphreys, United States Weather Bureau, has kindly read the manuscript and has offered valuable suggestions for which the writer is greatly indebted.

AN INVESTIGATION OF TEMPERATURE AND FROST CONDITIONS IN THE CRANBERRY MARSHES OF WISCONSIN.

INTRODUCTION.

Cultivation of cranberries confined to three States.—The cultivation of cranberries in the United States is confined mainly to three States—Massachusetts, New Jersey, and Wisconsin. In Massachusetts the cranberry-growing region in turn is limited almost entirely to the counties of Plymouth, Barnstable, and Bristol; in New Jersey, to Cape May, Atlantic, Gloucester, Burlington, Ocean, and Monmouth counties; and in Wisconsin, to Wood, Jackson, Juneau, and Monroe counties in the Wisconsin River Valley, and to Waushara and Winnebago counties in the Fox River Valley. (Fig. 1 for map of Wisconsin.) For several years there has been a marsh in the village of Cameron, Wis., and recently one was started in the Lake Superior region near the town of Ashland, Wis. The cultivation is slowly extending to Michigan and Minnesota, and even Oregon, but the cultivated marshes in the three states last named are at present comparatively of no importance. There are, of course, wild cranberry marshes in several of the Northern States, but the berries picked therefrom are seldom sufficient to supply even local needs. They are of little consequence as compared with the fruit produced in the cultivated marshes of Massachusetts, New Jersey, and Wisconsin.

The cultivation of cranberries as an industry is by far older and more successful on Cape Cod than elsewhere. Nearly every bog, whether large or small, on the Cape, has been converted into a cranberry marsh, and there we find the highest state of cultivation, the bogs being almost invariably sanded, well drained, and free from weeds. The Massachusetts bogs are individually small as compared with those found on the extensive moorlands of New Jersey and Wisconsin; and often one cranberry marsh in Massachusetts is made up of several small sections. That of the Federal Cranberry Company, near South Carver, Mass., which annually produces about 10,000 to 14,000 barrels of berries from a total area of 180 acres, is composed of 18 little bogs, separated naturally by hard land, but connected, nevertheless, artificially by ditches for the purpose of flooding; while, on the other hand, the Wisconsin moorlands are extensive and often stretch for many miles. The Wisconsin River Valley, the chief cranberry-growing section of the State, comprises an area of about 800 square miles, 550 of which are marsh land, the remaining portion being "islands" or hard land. In topography, the moorland sections of New Jersey more nearly resemble those of Wisconsin than they do those of Massachusetts. The average Massachusetts crop is about 300,000 barrels, while New Jersey and Wisconsin contribute 150,000 and 75,000 barrels, respectively.

Occurrence of low temperatures and frost in moorlands.—During clear cool nights the air usually is much colder over bottom lands, where the cranberry grows, than on neighboring slopes and uplands. This is especially true when but little wind or a calm prevails. During such nights the ground loses its heat rapidly by radiation, and the air lying immediately above is cooled. When cold heavy air lies over uplands and slopes it gradually settles through gravity to lower levels, being replaced by warmer air brought from above, which is in turn cooled. In fact, a gradual descending flow is established from the uplands to the valley, so that the cold air of the hilltops is drained away. Quite frequently crops in bottom lands suffer severely from frost, while on neighboring uplands the temperatures are not injurious. It is well known that the tobacco fields on the slopes of the Connecticut River often escape injury when damaging frosts occur lower down. The cranberry, moreover, has its habitat only in the bottom

lands where frost is most likely, but protection may be afforded by covering the bog with water stored in adjacent reservoirs.

Cultivating, draining, and sanding.—Protection to a considerable extent may also be obtained by cultivating, draining, and sanding the cranberry marsh. In bottom lands the vegetation is generally dense and the soil damp. Leaves and grasses are excellent radiators,

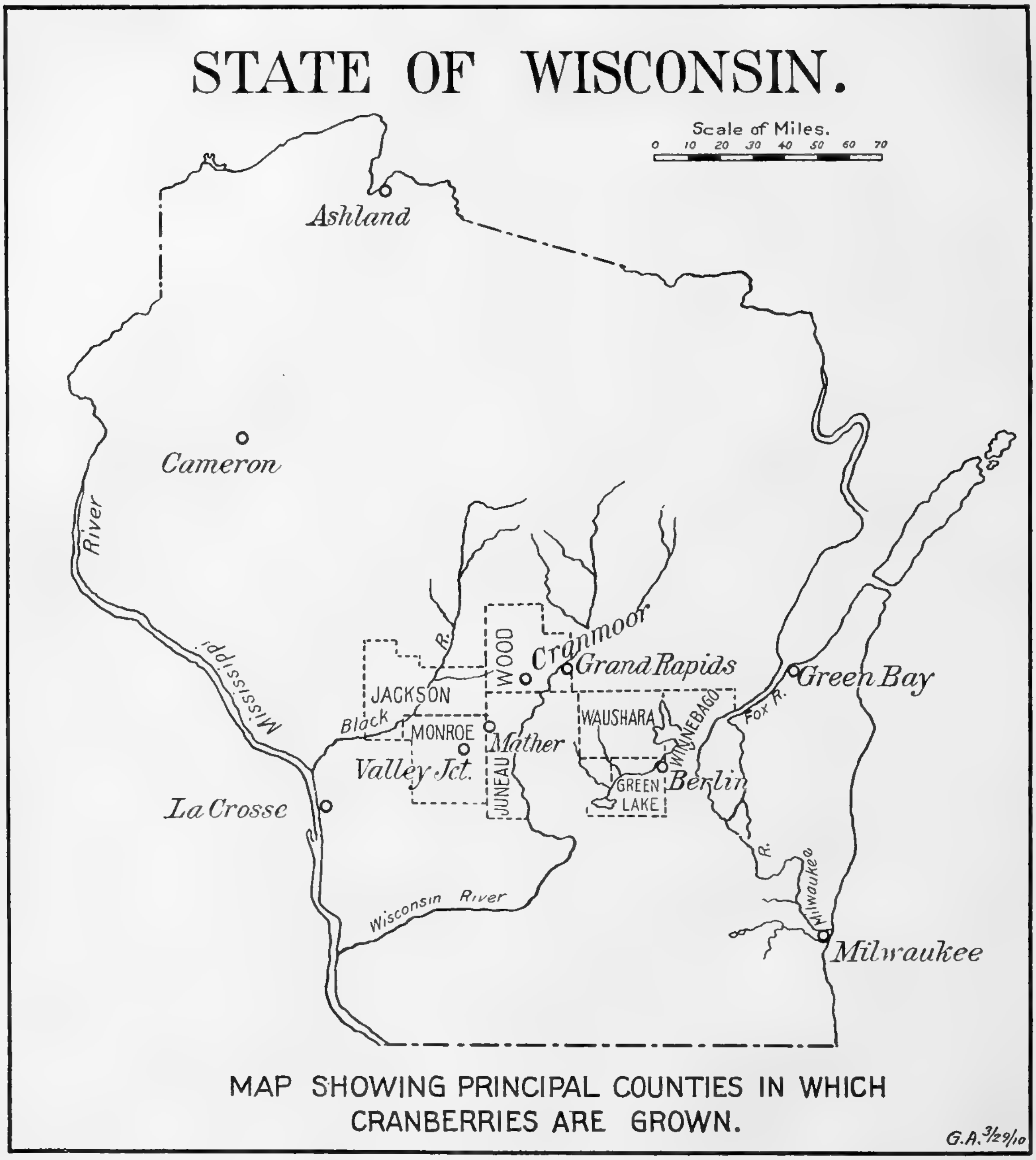

Fig. 1.—Map showing principal counties in which cranberries are grown.

and consequently lose their heat rapidly. The heat lost by radiation passes through the air, and does not warm it if the air is dry; but when the air is moist some of the heat is absorbed. Moreover, where the vegetation is dense, the soil beneath is screened from insolation, so that it is heated but little by the sun during the day, and has but a small supply of heat stored up. As a consequence the temperature of air lying over a field with a dense growth of vegetation is

relatively low during any cold clear night. Cultivation, by reducing the amount of vegetation, permits greater heating of the soil during the daytime, and consequently there is a larger store of heat to give out at night.

The peat soil found in bottom lands, on account of its capillarity, brings water to the surface, and the cold produced by the evaporation of this moisture is considerable. This is especially the case where the drainage is poor. Ditches, run at frequent intervals in the marsh, serve to drain the water from the surface and to reduce the amount of evaporation; and, at the same time, to conduct water of comparatively high temperature from adjacent reservoirs to the bog when frost threatens.

The moisture at the immediate surface may also be reduced by sanding—placing a layer of sand on the surface of the peat—because sand, almost wholly lacking in capillarity when coarse, does not bring the water to the surface. Moreover, sand on account of its low specific heat is warmed more easily, and acts as a conserver of heat. A sanded surface absorbs solar radiation tolerably well, and gives out heat by radiation only slowly. It cools largely by conduction to the atmosphere, thus serving to modify night temperatures by heating the air lying above.

Very few of the Wisconsin bogs have been sanded, and many have a rank growth of vegetation, grasses and ferns often attaining a height of 2 feet or more. Frequently canebrakes and sagebrush are found. The uprights from the cranberry vines are usually more than 6 inches in height, and occasionally 12 inches or more. The growth of the vines is very rank, and the marshes are seldom kept clean, so that even when the vines are laden with berries, one's attention is attracted to the vegetation rather than to the fruit. On the other hand, the Cape Cod marshes are invariably sanded and the vines are thin, the uprights seldom reaching a height of more than 5 inches, as the coarse sand employed dwarfs the vines. The berries, moreover, are usually so plentiful that one hardly notices the vines. The contrast between the Massachusetts marshes and those of Wisconsin is so pronounced that the growers in Wisconsin have been said to raise vines, and those on Cape Cod berries. This statement has some foundation in that the yield per acre on the Cape is about double that in Wisconsin. The marshes in New Jersey perhaps take middle ground between those in Massachusetts and Wisconsin. They are usually well cultivated, but only infrequently sanded. In fact, not 15 per cent of the New Jersey bogs are sanded. The growers there prefer to confine the cranberry culture to the natural peat soil, believing that it produces a crop of better quality than does a sanded bog, and that the expense of sanding is not justified by the increased returns. The right kind of sand is near at hand for the Cape Cod growers, but it is not easily available for many of the growers in New Jersey and Wisconsin. A coarse sand, resembling gravel, is ordinarily used, fine sand packing too hard and being therefore valueless.

The drainage in the bogs of Cape Cod, moreover, is excellent, the marshes during the growing season usually being as dry as an ordinary prairie—in strong contrast to the dampness of the Wisconsin bogs. The little need for reflowing on the Cape permits the growers there to keep the ditches dry during the summer season, but the Wisconsin growers are obliged at all times to keep a certain amount of water in the ditches in order to facilitate reflowing when frost is expected. The Wisconsin marshes are consequently more or less damp during the entire season. Cultivation, moreover, is practiced on Cape Cod, preventing the rank growth of vegetation and weeds that screen the soil from the sun's rays. Cultivating, draining, and sanding thus serve to cause higher soil temperatures in the daytime, and, as a result, relatively higher air temperatures at night.

These facts—the advantages gained from cultivating, draining, and sanding—were quite apparent to the writer after a preliminary investigation; and an effort will be made in this report to show in detail, by figures, the relation between the air temperature and the character of the soil and vegetation lying beneath.

Enemies to the cranberry crop.—The great enemies to the cranberry are frosts, floods, droughts, worms, and fire; and while the damage from frost is seldom very great in Massachusetts and New Jersey, frost is the berry's greatest enemy in Wisconsin. The meteorologist is

chiefly interested in the frost problem, as far as cranberry growing is concerned. However, floods and freshets during the growing season frequently work havoc with the cranberry crop, and it was because of the floods in the spring of 1908 that the crop in the vicinity of Berlin, Wis., was nearly a complete failure. In that year it was not possible to completely draw off the winter flow until the last of June, instead of in May as usual, and consequently the crop of berries in some bogs was confined to the tops of the vines while in others the crop was a total failure. Such surplus of water not only destroys the crop of the current year, but also weakens the vines so that they show the injurious effects for several years afterwards. The freshets of the spring and summer of the year 1906 were responsible for great damage to the New Jersey crop. If a flood covers the marsh during extremely warm weather there is damage to the vines and berries from scalding, the reflection of the heat from the surface of the water cooking the berries until they resemble baked apples. This liability to damage is always considered by the growers in reflowing their marshes in order to drown the vine and fruit worms, and it is necessary to select a period of cool and cloudy weather, if possible, so as to get the best results with the least injury. Damage is also liable from lack of water, not only in the insufficient supply available for reflowing the marsh for frost protection or otherwise, as in Wisconsin in 1909, but because in seasons of great drought the vines become parched and extensive fires are likely to occur. As a result of the drought of 1894, 95 per cent of the vines in the Wisconsin River valley were destroyed by fire, but the marshes have since been replanted. In 1909, 60 to 75 per cent of the Wisconsin crop was lost in the severe frosts of September because of lack of water for reflowing.

Comparison of temperatures in Massachusetts, New Jersey, and Wisconsin.—From a study of the temperature conditions in the three states during the growing season it is evident that the temperature is usually much lower in Wisconsin than in the eastern cranberry-growing sections. From a comparison made between temperature readings observed in shelters on hard land at Plymouth, Mass., Whitebog, N. J., and Mather, Wis., in the midst of the respective cranberry districts, for the months of May and September, 1906—critical months in the cranberry industry and fairly typical ones—it was found that the minimum temperature at Plymouth averaged higher by 5.1° in May and 4.5° in September than at Mather; while at Whitebog, for the same months, the minimum temperature averaged 8.1° and 7.6°, respectively, higher than at Mather. The average readings at the respective stations were as follows:

	May.	September.
	°	°
Mather, Wis.	41.9	50.5
Plymouth, Mass.	47.0	55.0
Whitebog, N. J.	50.0	58.1

The differences between these averages represent approximately the relation between the minimum temperature readings in the bogs in the various States, although for purposes of comparison it was found necessary to use readings made on hard land. The first frost in the New Jersey bogs in autumn usually occurs from two to three weeks later than in Wisconsin. In 1906, for instance, the first light frost at Whitebog occurred on October 8, and a heavy frost was not reported until October 11, while in Wisconsin the first frost was noted September 14[a] and the first killing frost on September 27.

Frost is so damaging in the Wisconsin bogs that means of protection from it must be the first provision made by the cranberry grower. Damaging frosts invariably occur there in the month of May, often in June, rarely in July, occasionally in August, and invariably again in the month of September; while midsummer frosts are unknown in the East and seldom occur in the month of June. In the East severe frosts do not occur so late in the spring or so early in the autumn; and consequently the seasons in Cape Cod and New Jersey are much longer than in Wisconsin. The season in the latter state is quite short, and it is only during a year in which

[a] About two weeks later than the average.

the crop season has a temperature far above the normal that the cranberry grower in Wisconsin, without means of protection from frost, can hope to gather even a fair crop.

Flooding to ward off frost.—It is apparent from the foregoing that, although the Wisconsin crop is usually smaller than that of either Massachusetts or New Jersey, it has special need of proper protection from frost, and hence the need of accurate frost warnings. The large majority of the Wisconsin and New Jersey marshes and a limited number of those in Cape Cod are connected with vast reservoirs, which are used for flowing the bogs in winter in order to prevent winter killing, and for reflowing during the growing and picking season for the purpose of warding off frost. In fact, as stated above, the first thought of the Wisconsin grower is to provide ample water supply. Some of the bogs in Massachusetts have no water supply, even for winter flowing, but all the bogs in Wisconsin and nearly all those in New Jersey have ample supply for this purpose. Growers usually turn on the winter flow in November and keep it on throughout the entire winter. Some Wisconsin growers take the winter flow off again about April 15, but the majority retain it until after the first of May, and a few until the last of May. Those who keep the flow on until late in May do so believing that the water prevents the hatching for that season of the fruit worms with which the marshes have been afflicted. Some growers who take the winter flow off the marsh early reflow during June and keep the water on for a few days, if a period of cool weather prevails, in order to guard against the fruit worm. It is supposed that the eggs are laid in May along the dams, and that if, through drowning, they are prevented from hatching during the month of June, the worms will not appear that season. As a period of three months is sufficient to mature the crop, should the water be retained until June 1, the cranberries would ordinarily be ripe for picking about September 1. Frequent reflowing, however, if the fruit is set, injures the vines and the berries as well. Moreover, in flowing and reflowing, damage is sometimes done to the crop by lime or other impurities in the water.

Most of the Wisconsin marshes can be reflowed in about four hours, but there are a few in that state that can not be satisfactorily flooded in anticipation of frost. In the marshes of the East, of course, as stated above, frosts are not as serious as in Wisconsin because of their more favorable geographical location. On Cape Cod, moreover, where intensive farming is practiced in the shape of sanding, draining, and weeding, there is not the same need for reflowing to ward off frost. Only about 30 per cent of the Cape Cod bogs can be reflowed as a means of warding off frost, and this can not be done twice in one week in more than 10 per cent of these bogs during a season of normal rainfall. In New Jersey somewhat better conditions as regards water supply prevail. Many of the bogs, as the excellent one at Whitebog, for instance, usually have ample water supply. With such limited water protection in Wisconsin as is usually available in Massachusetts bogs, success in the industry would be quite impossible. In reflowing a marsh the amount of water used depends upon the severity of the frost expected; sometimes it is sufficient merely to raise the water in the ditches; at other times to bring it up to the surface of the marsh; and, in extreme cases, to completely cover the vines and berries.

The Appleton marsh at Mather is a typical Wisconsin bog, and is usually provided with ample water supply. (Figs. 2, 3.) The reservoirs, both upper and lower, are largely floating bogs. Wide ditches connect the reservoirs with the cultivated sections and smaller ditches run through the sections from 80 to 100 feet apart. Water is usually present in the ditches to a depth of 1 to 2 feet, the surface of the water averaging perhaps about 12 inches below the surface of the marsh itself. These ditches are provided with gates to regulate the flow from the reservoirs. There is also a gate at the foot of the marsh (marked "B" on Fig. 3), which is shut during flooding and opened later in order to drain the water off. While 3 acres of reservoir are generally sufficient for flooding 1 acre of vines, yet the acreage of the marshes of Wisconsin usually has about one-tenth planted in vines, and the rest is given over to reservoirs and protection of water rights.

Previous knowledge of low temperatures in the Wisconsin bogs.—It has been known for many years that the minimum temperature in the Wisconsin bogs on clear cool nights falls far below the readings of the instruments at the nearest Weather Bureau station, and that frost often occurs in these bogs when there is no evidence of it on hard land. Prof. Willis L. Moore, now Chief of the United States Weather Bureau, was the first forecaster to give this subject special attention. It was in 1893, while in charge of the Milwaukee office, that he visited several of the bogs in the Wisconsin River valley. Later, other officials from time to time have visited these marshes. Professor Whitson, of the Wisconsin Experiment Station, undertook an investigation in 1904 in connection with the Branch Experiment Station located at Cranmoor. As a preliminary to the investigation started by the United States Weather Bureau, efforts were made to secure reliable data from various Wisconsin growers relative to the occurrence of frost and freezing temperatures during previous years, but it was found that very few of them had kept a record of any value. Some data, however, have been furnished by Mr. C. H. Johnson, manager of the Wyatt and Purdy marsh at Valley Junction. His statement shows that during

Fig. 2.—Appleton marsh, Mather, Wis., showing north section of bog, also brush where lower reservoir is located. View from upland. Directly beyond the brush is located the main section. Shelters at Stations 3 and 4 appear on the extreme left.

the period of twenty years from 1885 to 1904, inclusive, frost usually occurred in the summer at Valley Junction before the end of August. In 1885 heavy frost was recorded on August 22, in 1890 light frost occurred as early as August 10, and heavy frost in the same year on August 23. In several years of this period frost occurred more than once during the month of August, but Mr. Johnson has no record of its occurring in July; however, in a few instances, frost has been observed in that month by other growers.

The frost which occurred on June 11, 1903, in Wisconsin, did much damage, and, as a result, less than half a crop was harvested in that year. Some of the growers lost nearly all, although others, because of their location and better facilities for protection, secured nearly a full crop. The frost of August 8, 1904, reduced the crop of berries to about 60 per cent of that usually secured. No damage resulted in marshes which had been flooded before the frost. Unfortunately, some of the growers did not have their ditches clean, and the water in them was low, so that there was great delay in reflowing; and, as a consequence, considerable damage was done by the frost.

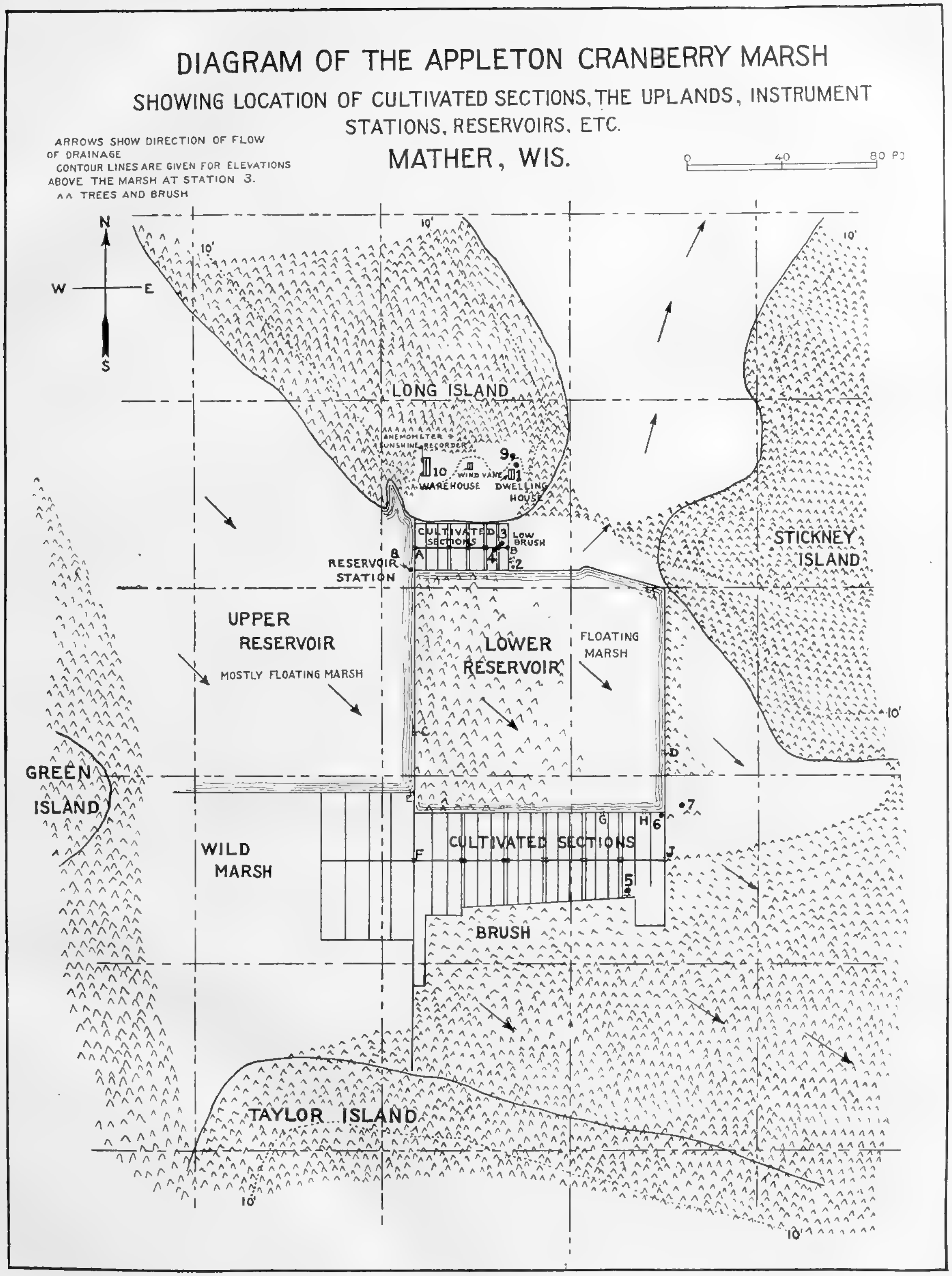

Fig. 3.—Diagram of the Appleton cranberry marsh, Mather, Wis.

This freeze of August 8 is remembered as more severe than any previous one in midsummer within the recollection of the Wisconsin cranberry growers. The day before, August 7, was cloudy, owing to a slight disturbance which was centered over Lake Michigan. The sun's rays were obstructed by dense clouds which kept the temperature of the air in the shade down to a maximum of 65° to 70°. The clouds, however, cleared away just at sunset and the wind, which was fresh during the day, became light in the evening, and the barometer rose steadily. Thermometers exposed in the vines in peat bogs at Mather and Cranmoor, Wis., recorded minimum readings of 29° and 26°, respectively, on the morning of August 8, and frosts were severe generally throughout the moorlands. No frost was reported that morning from any of the regular Weather Bureau stations, except Escanaba and Houghton. The minimum temperature at La Crosse, Wis., was 48°; Green Bay, Wis., 45°; Duluth, Minn., 50°; and St. Paul, Minn., 48°—all being readings from instruments located in shelters on the roofs of

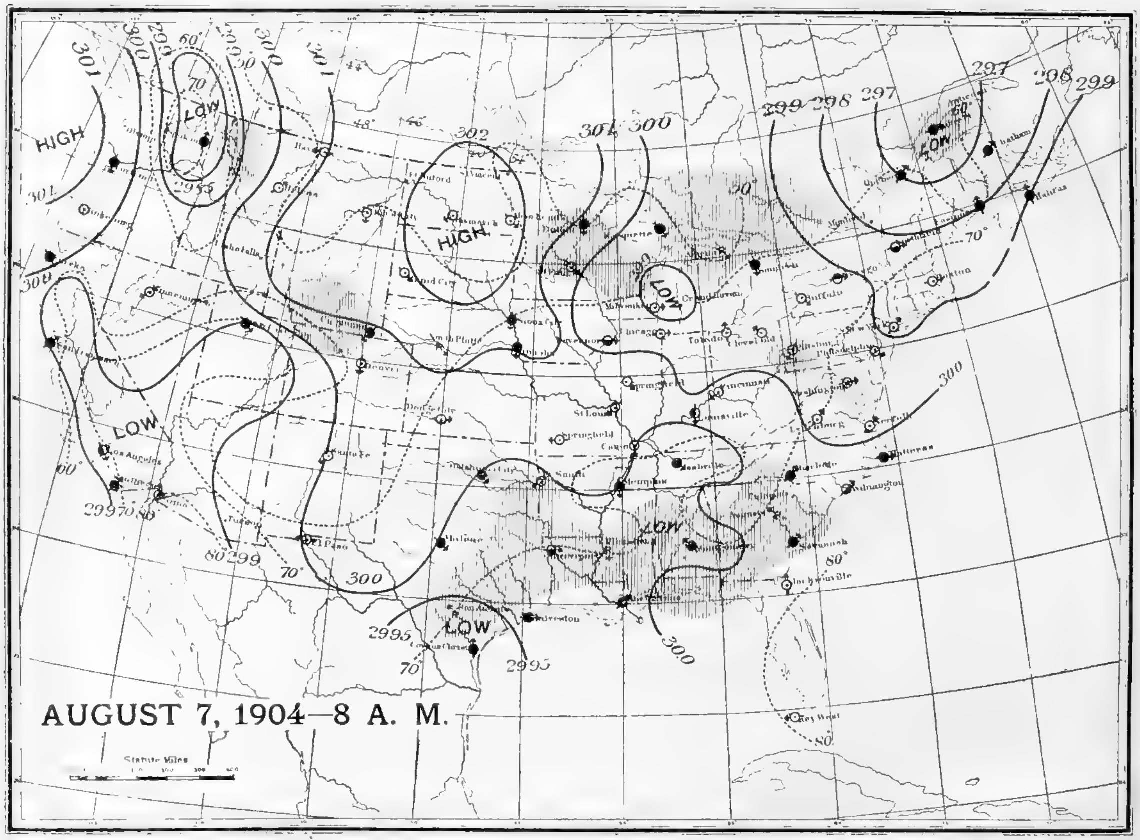

FIG 4.—Daily weather map, 8 a. m., August 7, 1904.

buildings. It would seem as if only an extraordinary condition could produce such low temperatures in midsummer.

A special study should be made of the weather maps of August 7–8 (Figs. 4, 5), showing the general weather conditions prevailing throughout the entire country. On August 7 the slight disturbance, marked "low," was central over Lake Michigan, while an area of high barometer, inclosed by the isobar of 30.2 inches, covered the Dakotas. The temperatures in North Dakota were in the forties, and the lowest reading was 40° at Minnedosa, Manitoba. The "low" remained nearly stationary during the greater portion of the day, causing the cloudiness and the relatively low day temperatures in Wisconsin, above referred to. It advanced eastward, however, by evening. On the morning of August 8 the high was directly over Wisconsin, with the center still inclosed by the 30.2-inch isobar.

As a general principle, it may be stated that the most favorable conditions as regards the production of low temperatures locally in the damp lowlands are an overcast sky during the

daytime, so that the soil is not heated by insolation; clearing at sunset, so that there may be active radiation at night; a rising and a comparatively high barometer which permits a settling of the cold air toward the ground; a fresh wind in the daytime, which reduces the temperature of the surface of the soil by the cold of evaporation, and which dies down at sunset and consequently does not interfere with the gradual settling of the cold air to the ground; and comparatively low humidity, as radiation from the ground through dry air is freer, or, in other words, the lower the humidity the less the absorption of heat by the air. On August 7–8, 1904, all the conditions were apparently present for the production of abnormally low minimum temperature, viz: Cloudiness and fresh breeze during the day, followed by clearing in evening, rising barometer, falling of the wind, and comparatively low humidity.

Beginning of the investigation.—As stated above, it was found that but few of the Wisconsin growers had kept any record of temperature and frost conditions in the bogs. Visits were

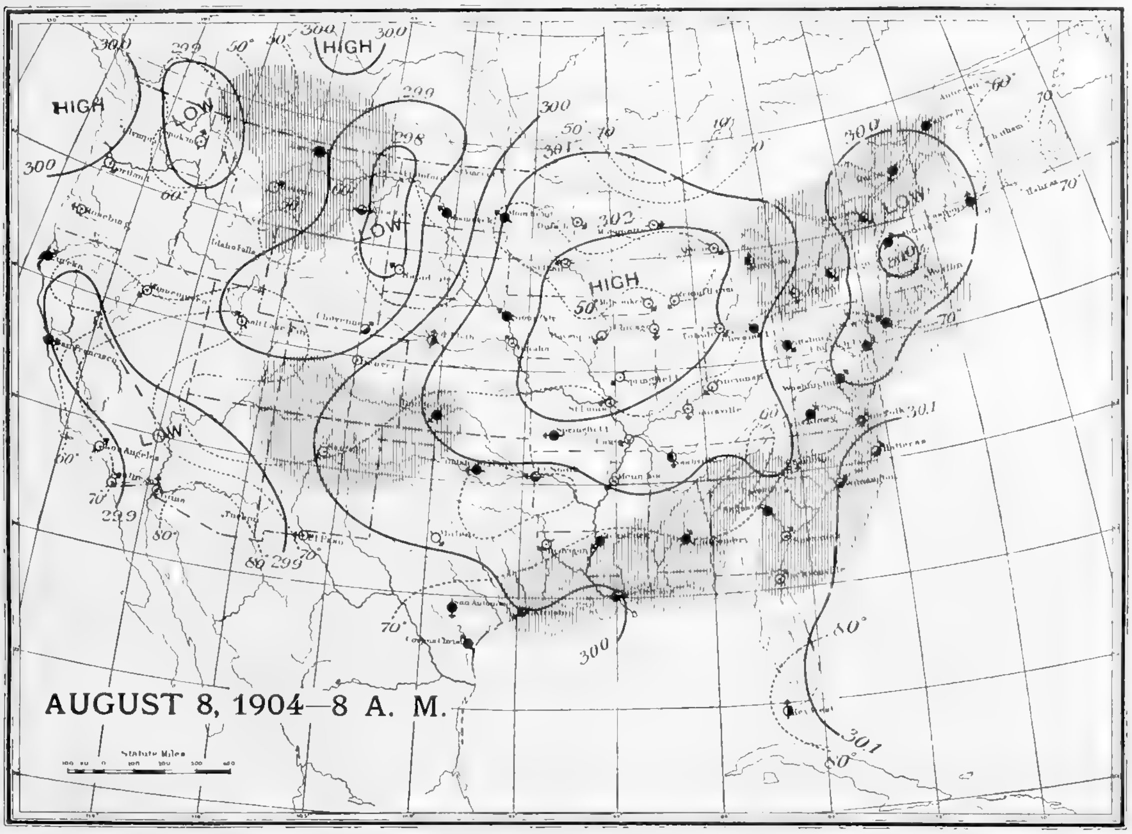

FIG. 5.—Daily weather map, 8 a. m., August 8, 1904.

made to several of the marshes and communication was had with many of the growers for the purpose of securing any available data in anticipation of the proposed investigation. These men are usually intelligent and keen, and intensely interested in their work, and consequently it is strange that so little attention had been given to the preservation of temperature records, as definite knowledge of the subject of temperature in the bogs should be of permanent value. Moreover, there had been a wide divergence of opinion among the growers regarding the problem which was being undertaken, but all seemed to be interested and willing to cooperate. The growers stated that occasionally frost attacked one section of a marsh and left the remainder untouched, without apparent cause; also, that damage was sometimes done to one marsh while another adjoining escaped injury. They were naturally puzzled over these unusual features. In the investigation which Prof. A. R. Whitson[a] had started at the Cranmoor Experiment Station in 1904, the observations were restricted almost entirely to artificial conditions

[a] Wisconsin Bulletin 119, A Report on Cranberry Investigation.

created for the purpose. The section at the Branch Experiment Station planted with cranberries is not representative of the Wisconsin cranberry marshes in actual operation, but rather of the conditions prevailing on Cape Cod. The plat of ground at Cranmoor is so small that the various thermometers used in Whitson's investigation were comparatively close together, and all were affected more or less by the same conditions. Whitson apparently lost sight of the fact that a thermometer exposed at any point is largely affected by its environment, as well as by the conditions at the immediate point of exposure. While Whitson has endeavored to lead the way, and to induce Wisconsin growers to adopt eastern methods of sanding, cultivating, and draining, the latter have been very slow to follow. For certain reasons that will develop later the majority of the Wisconsin growers have not considered it advisable to follow the Massachusetts method in sanding and cultivating.

It was deemed best to conduct the investigation by the Weather Bureau as far as practicable in typical bogs, fully representing the various conditions existing. In beginning this work in June, 1906, special cranberry marsh stations were established at Cranmoor, Mather, Berlin, and Cameron and continued throughout the season. The Cranmoor station was at the Wisconsin Branch

Fig. 6.—Fitch cranberry marsh, Berlin, Wis., looking north along county line ditch where Stations 2, 3, and 4 are located. Fog in the distance on north side of the marsh just after daybreak.

Experiment Station in charge of Professor Whitson, referred to above. It is situated in the center of the Cranmoor region, and adjoins the well-known Gaynor-Blackstone marsh. The Appleton marsh at Mather was selected because it is typical of the Mather district. (Figs. 2, 3.) Both Cranmoor and Mather are located in the extensive moorlands of the Wisconsin River valley. The Berlin station, established at the Fitch marsh, is 8 miles northeast of the city of Berlin in the Fox River valley, and in a much less extensive moorland. (Fig. 6.) The Fitch marsh is old and fairly productive, but poorly drained and lacking in satisfactory means for reflowing. The Cameron station was situated in the northwestern part of the State, and the marsh at that point was selected on account of its geographical location and because it was in a narrow gully between stretches of hard land. At these four stations special local observers were secured. While at Cranmoor, the observer was Mr. O. G. Malde, an assistant to Professor Whitson of the Experiment Station, at the remaining stations the persons employed were managers of the respective marshes. All of the local observers except the one at Cameron had long experience in making observations. In July, 1906, moreover, an experienced observer was sent from the Chicago office to Mather to conduct observations in detail, and the writer

himself spent the greater portion of the season in personal work at Mather and Berlin in order to secure the data first-hand.

An extensive equipment was secured for the Mather and the Berlin stations for the purpose of going into the subject exhaustively, and thus finding the true reasons for the comparatively low temperatures in the bogs and their great variation. It was expected that the work in 1906 would be merely preliminary and that no definite results could be secured in so brief a period; that only sufficient data could be obtained in the first season to prepare more definitely for the work of 1907. This proved to be true, as considerable experimenting was required to determine how and where the various instruments should be exposed. Moreover, the soil thermographs, ordered from abroad the previous winter for this special work, did not arrive in this country until almost the end of the season, and the results obtained from some of them for the month of September, while they were in operation, are of little value. It was extremely difficult to adjust them so as to secure accurate records. Furthermore, the observations made at Cameron were found to be unreliable, and they have not been used in this discussion. The result of the experience with the Cameron observer suggests that observations for scientific purposes should never be intrusted to an untrained observer, even though he receive compensation. The data must be accurate; otherwise the deductions and conclusions have little value. The observations appearing in this bulletin, with the single exception of Table 12, were made by regular employees of the Chicago Weather Bureau office.

The stations at Berlin and Cameron were closed at the end of the season of 1906. In 1907 the cooperation of the Cranmoor Experiment Station was continued and the work at Mather was much enlarged, trained observers from the Chicago office conducting the observations there from early in May until the end of October. Also during the seasons of 1908 and 1909 a limited number of observations were secured from Cranmoor and Mather. Moreover, observations made at these two stations, beginning with 1905, have been telegraphed daily to the forecast center at Chicago for the use of the forecaster in issuing frost warnings for the Wisconsin cranberry marshes. The Berlin marsh had no facilities for telegraphing and its report was not transmitted daily.

Characteristics of stations at Cranmoor, Berlin, and Mather.—The three marshes selected for the investigation are widely separated and fairly representative of the conditions prevailing in Wisconsin marshes. Owing to the high state of cultivation at the Cranmoor Experiment Station there is usually no need for reflowing during the entire cranberry season in order to ward off frosts. This is in strong contrast to the conditions prevailing in the Gaynor-Blackstone marsh, immediately adjoining, which represents the average conditions found in the Wisconsin bogs. The Appleton marsh at Mather differs from the Gaynor marsh in that the greater portion of it has been sanded. It was sanded in 1898 to a depth of about 2 inches, and sanding was again done in the winter of 1905–6, but in the meantime a layer of peat an inch or two in thickness had accumulated over the former sanding. Having ample water supply, it can usually be reflowed in about four hours. This marsh was fairly dry during the season of 1906, but in 1907 it was, unfortunately, at frequent periods very wet. This latter condition was due primarily to heavy rains and to the breaking of the dams in the reservoir of a marsh immediately adjoining. The water "backed up" on the Appleton marsh at times, and it was drained off with difficulty; and consequently, the conditions as regards moisture were not as typical of that marsh in 1907 as in 1906 and the exposure of the instruments, as a result, not as satisfactory. Some of the instruments exposed at the surface of the bogs were, at times, covered with water. The reflowing in anticipation of frost also affected the exposure of the instruments, but that was a complication that could not be avoided, and in these cases, the readings have either been estimated or thrown out entirely.

The Fitch marsh at Berlin (Fig. 6), as stated already, could be reflowed only with great difficulty, and it was seldom attempted, the course usually taken in anticipation of frost being to raise the water high in the ditches. The marsh was naturally wetter than the Appleton marsh, the drainage not being as good. In the season of 1906, when observations were made

at Berlin, there was little change in the amount of moisture in the bog, except immediately following the heavy rain of July 29, when 4.99 inches fell in a few hours during a thunderstorm. As a result of this fall over the bog and the drainage from the surrounding country, the water was over a foot in depth on the marsh, and several days were required to drain it off.

The stations that were established at the Appleton marsh at Mather in 1906 were continued during the season of 1907 without change as regards location, although the character of the equipment was improved considerably. (Fig. 3 shows plan of marsh, giving locations of cultivated sections, reservoirs, uplands, brush, woods, etc. The figures mark the stations and the letters mark the gates that control the water supply.) In comparing Figures 2 and 3 it should be noted that in the photograph (Fig. 2) the marsh in the foreground, which is intersected by numerous ditches for the purpose of flowing and reflowing, is identical with the cultivated sections in which Stations 3 and 4 are located, appearing in Figure 3. The adjoining uplands or islands [any stretch of hard land in the bog region is called an island], have an elevation of 10 to 15 feet above the surface of the marsh. The peat and muck in this marsh is

Fig. 7.—Station 1, Mather, Wis.

Instrument shelter on upland near dwelling. Photograph made in 1906. Shelter lowered from an elevation of 8 feet to 5 feet in 1907. Rain gages about 20 feet to the right. They do not appear in the picture. Garden in the background where Station No. 9 was located.

from 10 to 25 feet in depth, and the soil of the surrounding islands is a sandy loam, mostly covered with grass, with brush and trees at intervals.

Equipment of the Mather Station.—The instruments at Mather were located at stations widely separated and in the midst of large sections as far as possible typical of the conditions prevailing at the points where the instruments were exposed. An exception was made in this respect at Station 7. The following was the equipment in operation in 1907:

Station 1, north of the dwelling house on Long Island. The shelter (shown in the photograph, Fig. 7, taken in 1906) was lowered in 1907, so that the floor was about 5 feet above the ground, instead of 8 feet as in 1906. Equipment: Maximum, minimum, and exposed thermometers, also air thermograph, all in the shelter. Station 1 was also provided with an Assman aspiration psychrometer, attached to the northeast corner of the dwelling, and two rain gages. A barograph was kept in the dwelling.

Station 2 (Fig. 8), in the bog over a dense growth of sphagnum moss, outside of the cranberry marsh proper. The moss probably reached to a depth of 6 feet, and, like a sponge, was saturated with water. The station had, however, the advantage of being outside the

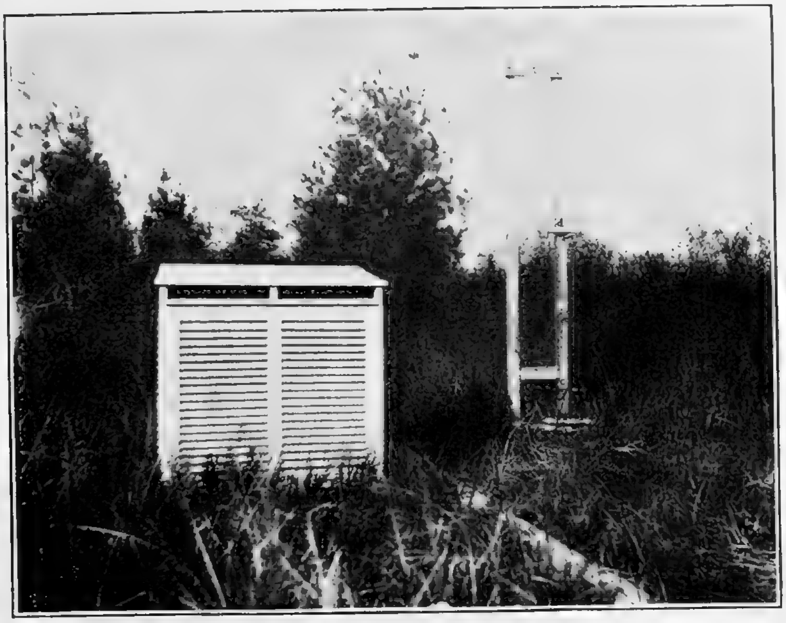

FIG. 8.—Station 2, Mather, Wis.

In bog over sphagnum moss and long grass outside cranberry marsh. Photograph made in 1906. Thermometers at various elevations up to 36 inches attached to posts in 1907.

FIG. 9.—Station 3, Mather, Wis.

Newly sanded, thinly vined. Photograph made in 1907. Grasses seen in the photograph were not present in 1906, and the vines were not so dense.

cultivated sections that were flooded in anticipation of frost, and consequently the conditions as regards moisture varied less here than elsewhere in the bog. Equipment: Air thermograph and maximum and minimum thermometers in the shelter about 5 inches above the surface of the marsh. Outside and immediately to the north of the shelter were two posts on which were fastened 6 maximum and 6 minimum thermometers facing south at the following elevations: Surface, $2\frac{1}{2}$ inches, 5 inches, $7\frac{1}{2}$ inches, 12 inches, and 36 inches; also minimum thermometers at additional elevations of 10 inches and 15 inches; 2 soil thermometers in the moss at depths of 3 inches and 6 inches, respectively; soil thermograph, the bulb of which was exposed at a depth of 3 inches in the moss.

Station 3 (Fig. 9), in the cultivated section was heavily sanded during the winter of 1905–6. It was thinly vined during 1906, and relatively so as compared with the other stations in the cranberry marsh in 1907, but the vegetation was then more dense than in the previous year. It may be considered as representing the best conditions on the bog as regards sanding, cultivating, and draining. Equipment: Minimum thermometer in the shelter at an elevation of about 5 inches above the surface of the bog; minimum thermometer in the open at the surface of the marsh, also at elevations of 5 inches and 36 inches above the marsh; maximum thermometers similarly exposed at the surface and at 36 inches above the marsh, the thermometers at 5 inches and at 36 inches being fastened to a post; air thermograph which rested on the surface of the soil; soil thermometers at depths of 3 inches and 6 inches, respectively; soil thermographs, the bulbs of which were similarly exposed.

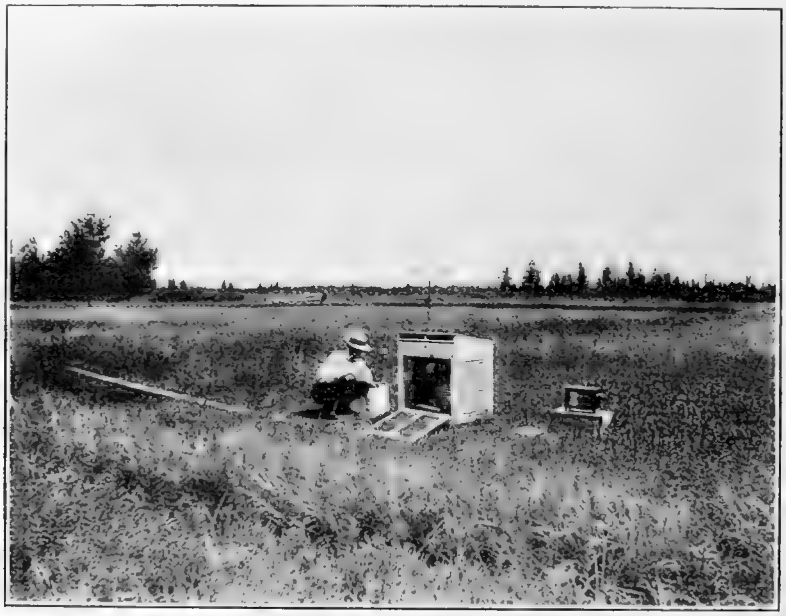

Fig. 10.—Station 4, Mather, Wis.

Newly sanded, heavily vined. Photograph made in 1907.

Station 4 (Fig. 10), also a heavily sanded section, but the vines and vegetation relatively dense. This exposure may be considered as representing the best conditions prevailing on the bog as regards sanding and draining. Equipment: Minimum thermometer in shelter at an elevation of about 5 inches above the surface of the bog; minimum thermometers in open, at the surface of the bog, and at an elevation of 5 inches; maximum thermometer at the surface of the marsh; an Assman aspiration psychrometer fastened to the shelter; soil thermometers at depths of 3 and 6 inches; soil thermograph, the bulb of which was placed in the soil at a depth of 3 inches; anemometer fastened to the top of shelter and attached to a single register inside, the cups of the anemometer being 4 feet 7 inches above the ground.

Station 5 (Fig. 11), in an uncultivated portion of the bog, but close to the cultivated sections. It had never been sanded, the soil being plain peat, and it had a dense growth of vines

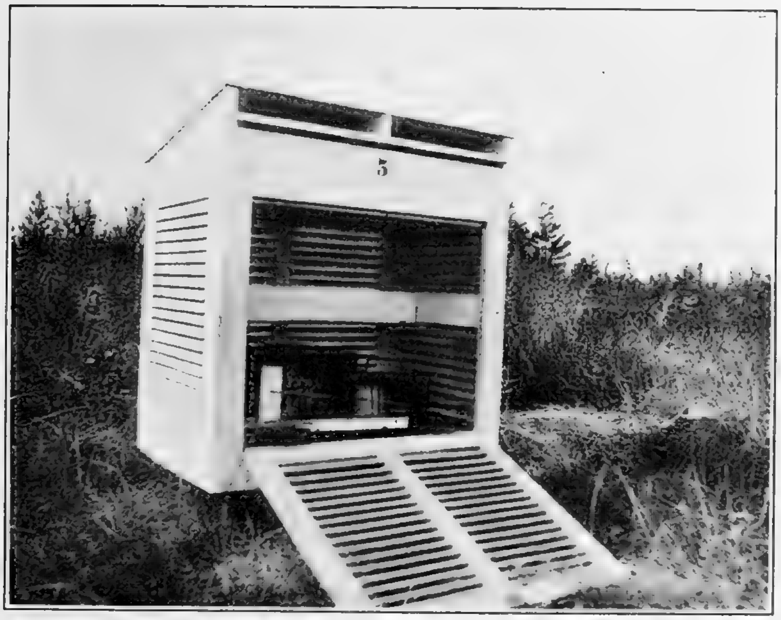

FIG. 11.—Station 5, Mather, Wis.
In uncultivated bog. Photograph made in 1906.

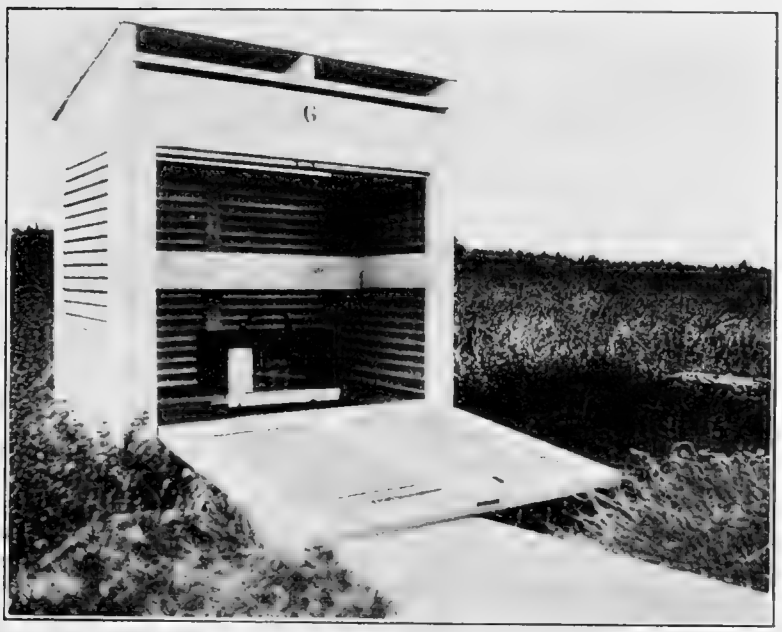

FIG. 12.—Station 6, Mather, Wis.
Old sanded, heavily vined. Photograph made in 1906.

and other vegetation, including numerous patches of sphagnum and wood moss. This location represents the poorest conditions on the cranberry marsh as regards cultivation and drainage, and it was consequently wetter than Stations 3 and 4. Equipment: Minimum thermometer in shelter at an elevation of about 5 inches above the surface of the marsh; minimum thermometers in the open at the surface of the bog, and at an elevation of 5 inches; maximum thermometer at the surface of the bog; air thermograph placed in the open on the surface of the marsh; soil thermometers exposed at depths of 3 inches and 6 inches; soil thermographs, the bulbs of which were similarly exposed. During the season of 1907, the vines surrounding the soil instruments died out, and gradually changed from the conditions prevailing in 1906. This was due to unavoidable trampling of the vines by the assistant who made the observations. With the purpose of maintaining the original conditions as far as possible, the exposures of these instruments were changed twice during August.

Station 6 (Fig. 12), in a cultivated section which had been sanded about 1898, but which had never been sanded a second time; so that a layer of peat an inch or two in thickness, formed from the decayed vegetation, covered the old sand. There was a dense growth of

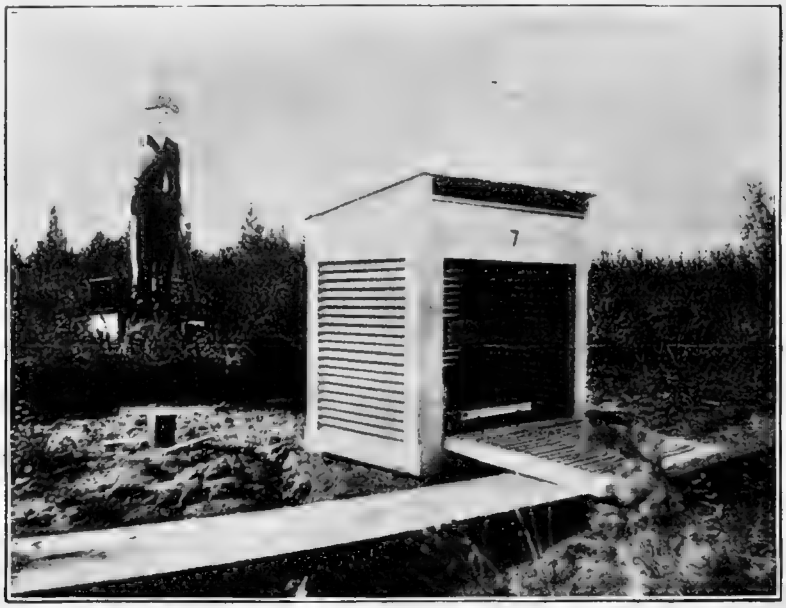

Fig. 13.—Stations 7 and 7a. Mather, Wis.
In scalped section and on moss adjoining. Photograph made in 1906.

vines around the station and the drainage was similar to that of Station 5. Equipment: Minimum thermometer in the shelter about 5 inches above the surface of the marsh; minimum thermometers in the open at the surface of the marsh, and at an elevation of 5 inches; maximum thermometer at the surface of the bog; soil thermometers at depths of 3 and 6 inches; soil thermograph, the bulb of which was exposed at a depth of 3 inches. The soil thermograph was fairly satisfactory for all months except October, when it became defective.

Station 7 (Fig. 13), located outside the cultivated bog in a section of bare peat, scalped especially for the purpose in 1906, in the midst of a dense growth of sphagnum moss. This station was at the lower end of the marsh, and consequently more damp than the cultivated sections. Equipment: Minimum thermometer in the shelter about 5 inches above the surface of the bog; minimum thermometers in the open at the surface of the peat, and at an elevation of 5 inches; maximum thermometer at the surface of the peat; soil thermometers at depths of 3 inches and 6 inches; soil thermograph, the bulb of which was exposed at a depth of 3 inches.

Station 8 (Fig. 14), the reservoir. This station was in a ditch about 4 feet in depth, and from 20 to 25 feet wide, lying between the floating marsh on the west and a dam on the east. Equipment: Water thermometer; soil thermograph, with the bulb exposed in the water at a

FIG. 14.—Station 8, Mather, Wis.

Reservoir showing wide ditch and floating bog. Observer taking an observation of water temperature.

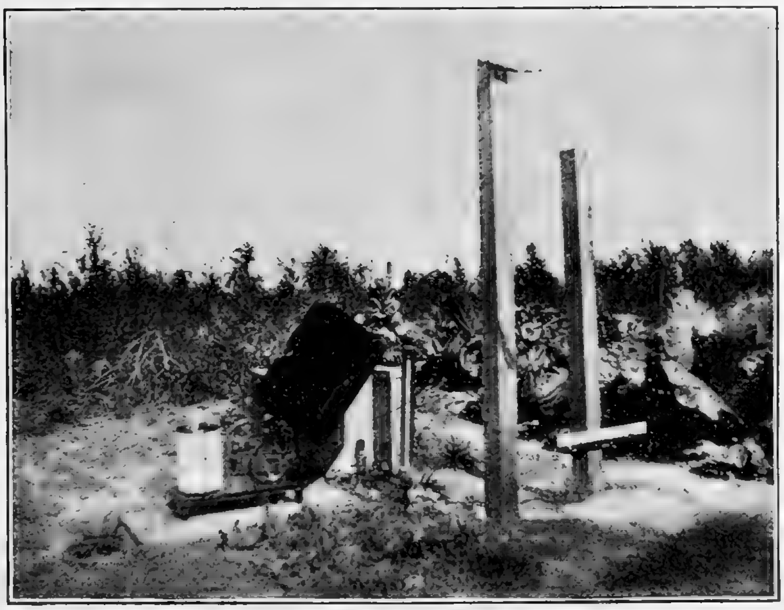

FIG. 15.—Station 9, Mather, Wis.

In garden on upland. Photograph made in 1906. This station was supplied in 1907 with additional thermometers in instrument shelter and attached to the posts up to an elevation of 36 inches.

depth of about 12 inches. This instrument although officially known as a soil thermograph might in this case properly be called a water thermograph.

Station 9 (Fig. 15), over sandy loam in the garden in the rear of the dwelling on Long Island. It was established for the purpose of making some comparison between the conditions on hard ground and in the adjoining bog. The garden was planted, but well cultivated and drained. Equipment: Minimum thermometer in the shelter about 5 inches above the surface of the soil; 6 minimum and 6 maximum thermometers facing south at the following elevations: Surface, 2½ inches, 5 inches, 7½ inches, 12 inches, and 36 inches, also minimum thermometers at additional elevations of 10 inches and 15 inches; soil thermometers at depths of 3 and 6 inches.

Station 10 (Fig. 16), the warehouse. Equipment: Anemometer and sunshine recorder exposed on the cupola of the warehouse, about 50 feet above the marsh, and about 35 feet above the ground on the upland. These instruments were attached to a double register in a room in the warehouse. The wind vane was exposed on a building near the warehouse.

Equipment of the Berlin Station.—It is hardly necessary to go into details regarding the equipment at Berlin (Fig. 6). The investigation there was confined to a portion of the year

Fig. 16.—Station 10, Warehouse, Mather, Wis.
Anemometer on cupola. Sunshine recorder on ridge of roof.

1906, with a rather incomplete set of instruments. The peat and muck in this marsh reaches to a depth of 20 to 26 feet, and there is a stretch of hard land on the immediate border about 3 feet above the surface of the marsh. The soil of this hard land consists of yellow clay. A short distance beyond there is a gradual slope to ordinary dark soil.

A portion of the equipment used in this discussion follows. Station 1, which was almost on the edge of the bog, was provided with an instrument shelter in which were exposed maximum and minimum thermometers and an air thermograph. There was also a rain gage close at hand. (Fig. 17.)

Station 2, over a peat bog which had been carefully weeded before the observations were begun. Equipment: Minimum thermometers exposed in the open at the surface and at an elevation of 5 and 36 inches, respectively, above the surface of the marsh.

The sections around Stations 3 and 4, to an extent of about 40 feet square, had been especially sanded for use in the investigation. The marsh, as a whole, had a rank growth of vegetation, and had never been sanded. At Station 3 were minimum thermometers exposed in the open at the surface and at 5 and 36 inches above the surface; also a soil thermometer at a

FIG. 17.—Fitch marsh, Berlin, Wis., showing car track on bog, dwellings, warehouses, and shanties. Cross in photograph shows location of Station 1 in 1906.

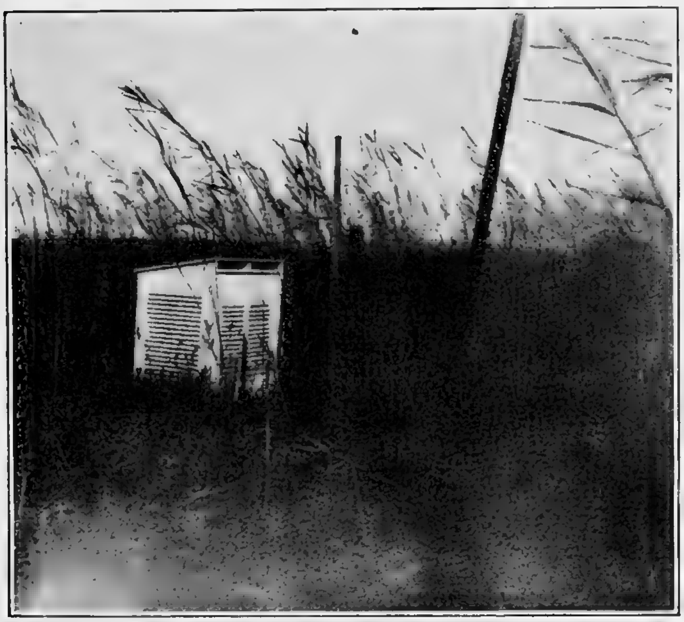

FIG. 18.—Station 5, Fitch marsh, Berlin, Wis. In ferns and canebrakes.

depth of 3 inches. This station well represents the best conditions obtainable from cultivating and sanding, and fair conditions as regards draining. Station 4 had the same character, except that it was slightly lower than Station 3, and consequently wetter through poorer drainage. The equipment consisted of minimum thermometers exposed in the open at the surface and 5 inches above. Stations 2, 3, and 4 were situated in a line about 100 feet apart. The thermometer shelters at Stations 2 and 3 may be seen in Figure 6, which gives a view of a considerable portion of the Berlin marsh at dawn. No shelter was used at Station 4. The shelters at the other stations on the bog were used for housing the recording portions of the soil thermographs during the short time that they were in operation. These instruments proved defective in 1906, and consequently the records have not been used.

Station 5 (Fig. 18), in a section termed the "ferns," about 1,000 feet north of Stations 2, 3, and 4. The equipment consisted of maximum and minimum thermometers placed at the surface of the bog and at an elevation of 5 inches, respectively. The upper thermometers here were not fastened to a post, but merely placed on top of a bed of vines and ferns, which were pushed down in a compact mass to provide a resting place for the instruments at the desired height. In all other instances at Mather and Berlin the instruments exposed at an elevation above the surface were attached to wooden supports. Station 5 was also provided with a soil thermometer at a depth of 3 inches. Some additional instruments were included in the equipment at the various stations, but it seems unnecessary to refer to them. The object has been to present in this report merely such observations made at Berlin as may supplement the more complete data at Mather.

The thermometers used in this investigation were all carefully tested in the Instrument Division at Washington before being shipped to the cranberry marshes; they were daily examined in order to detect possible defects, and exchanges in the instruments were made occasionally between the various stations at both Mather and Berlin, so as to obviate the effect of any possible instrumental error.

DISCUSSION OF THE PROBLEM.

Minimum temperatures in shelters, and in the open, both at 5 inches above the surface.—In order to determine the relation existing between the readings of thermometers in shelters and those exposed in "the open," as are the instruments generally used by the cranberry grower, minimum thermometers were placed at various stations at Mather, in "the open" at 5 inches above the surface, corresponding in elevation to the thermometers placed in the respective shelters. During the day the surface of any solid upon which the sun shines becomes hotter than the air above it, because the solid is a much better absorber of heat than the air; while at night, especially when the sky is clear, the air loses its heat more slowly than a solid, such as vegetation or soil, because the air is a very poor radiator of heat. The readings of the instruments in the shelters indicate the true temperature of the air at the various stations, while the readings of the thermometers outside the shelters, strictly speaking, represent the temperatures of the instruments themselves, but they may be considered to indicate approximately the temperature of the vines and plants at the height of 5 inches. It is probable that the temperature of the vegetation was even lower than that recorded by these exposed minimum thermometers. The differences, however, can not be large, because the exposed minimums often registered readings as low as 28° without apparent damage to the vegetation. It is quite impracticable to secure daily readings of the temperature of plants or leaves that may be comparable. The reading of the thermometers exposed in the open might properly be termed "sensible temperatures," but in this bulletin all such readings, whether maximum or minimum, will be referred to as *exposed readings, or readings in the open.*

Table 1 shows in detail the daily readings and differences at each station, and Table 1*a* shows the averages for the various months and for the season of 1907. The average difference for the entire season was least at Station 9 on the upland, 1.4°, where there was a clean soil and very little vegetation. The average difference *on the bog* was least at Station 3, 2.5°, also where

the vegetation was thin; and at Station 7, 2.7°, over peat, in the scalped piece, but closely surrounded by sphagnum moss. The difference was greatest at Station 5, 3.6°, and at Station 6, 3.7°, where the vegetation was dense. The average difference at Station 4 was 2.6°—but slightly greater than that at Station 3. This difference was not larger because the location of the thermometers exposed at the 5-inch height at Station 4 was thinly vined as compared with the other portions of that section. In fact, a close relation was found to exist between these differences and the density of vegetation. On account of the great radiation of heat from vegetation, the exposed minimums were relatively much lower where the vegetation was dense than where the soil was clean. At all stations the least difference usually occurred during the month of May, with an increase irregularly toward midsummer with increasing vegetation, and then a falling off, which was later followed by another maximum in October. The gains and losses were not uniform at the various stations, simply because there was a lack in uniformity in the changing of the vegetation. The conditions changed because there was trampling of the vines and grasses, more at some stations than at others, and for various other reasons. It is probable that if all the conditions as regards vegetation, soil, and moisture were identical for the whole bog, or even for the section in which the instruments were located, approximately the same differences would occur at each station on each night; but the amounts of these differences would probably change as the nights became longer or shorter, and as the character of the weather varied from day to day. Moreover, if a uniform relation existed during the entire season as regards vegetation, between the places of exposure of the outside thermometers and the location of the shelter itself, the relation between the various differences of the readings inside and outside would not change materially.

The reason for the great differences in October is not because of increasing vegetation, but rather in spite of *a decrease*. It is due to the fact that the nights were much longer and comparatively cold, thus permitting great loss of heat from the plants by radiation and conduction. The greatest difference at Station 2 was 6.5° on October 11; at Station 3, 4.7° on October 31; at Station 4, 6.3° on October 22; at Station 5, 9.9° on July 10; at Station 6, 7.9° on July 16; at Station 7, 6.4° on May 18; and at Station 9, 7.2° on August 10. There were, on the other hand, many days when there was only a slight difference in the readings, and there were a few instances in which the outside thermometers read slightly higher than those exposed in the shelters. When the difference was great at one station, it was usually relatively great at the other stations; likewise, when there was but a slight difference at one point, a like condition prevailed at the other stations. On nights of slight differences the sky was invariably overcast, while clear to partly cloudy conditions with comparatively high barometer prevailed when great differences occurred, which fact indicates that radiation is the controlling factor. Formation of dew on the bulbs of the outside thermometers, followed by a freshening of the wind and consequent evaporation of the moisture, was occasionally the cause of low readings of certain of these instruments. Dew doubtless often formed and disappeared during the night without being observed.

The mean depression of the outside thermometers below those in the shelters at the six stations on the bog for the entire season of 1907 was 3°, and, including the record at Station 9 on the upland, the depression for the same period was 2.8°. Prof. Willis I. Milham,[a] in experiments conducted at Williamstown, Mass., on thirty-six cold and generally cloudless nights in the winter of 1904–5, while the ground was covered with snow, found that the average difference between the readings of a minimum thermometer exposed in a shelter and one in the open was 3.9°, and that the greatest difference on any one night was 7.8°. In making comparisons between these figures and the results at Mather over vegetation, it should be borne in mind that the latter are for the entire growing season without regard to the cloudiness and the temperature prevailing. The average difference on *clear* nights at Mather no doubt equals that determined by Professor Milham.

---

[a] Monthly Weather Review, July, 1905.

The temperature in the shelter on the upland at Station 1 may be considered the standard with which other temperatures observed at Mather during this investigation should be compared. However, the readings at Station 1 have not been included in Tables 1 and 1*a*, because it was first desired to determine the relation existing between shelter and exposed temperatures at the same elevation. By referring to Table 18, which will be discussed in detail in turn, it should be noted that there is a great difference between the shelter readings on the bog and on the upland, the difference varying with the character of the soil and vegetation, as in the case of the observations in shelter and in open at the various stations, referred to above in connection with the discussion of Tables 1 and *1a*. Where the differences were great between the readings in shelter and open, relatively large differences were noted between the readings in those shelters and the shelter at Station 1; while, on the other hand, at stations where smaller differences were observed, the shelter readings approached more nearly the shelter readings at Station 1.

TABLE 1.—MINIMUM TEMPERATURES IN SHELTER AND IN OPEN AT 5-INCH HEIGHT, FOR EACH STATION, TOGETHER WITH THE DIFFERENCE BETWEEN READINGS, MATHER, WIS., 1907.

Day of month.	Station 2.			Station 3.			Station 4.			Station 5.			Station 6.			Station 7.			Station 9.		
	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.
MAY.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					
11																					
12	36.7	35.2	−1.5	37.3	35.4	−1.9	37.4	35.4	−2.0	37.0	35.0	−2.0	37.0	34.2	−2.8	36.7	35.1	−1.6	37.4	36.7	−0.7
13	*61.0*	*60.0*	−1.0	*61.6*	*59.6*	−2.0	*61.4*	*59.0*	−2.4	*61.2*	*58.9*	−2.3	*60.9*	*57.2*	−3.7	*61.0*	*58.0*	−3.0	*61.5*	*59.8*	−1.7
14	45.0	45.0	0.0	45.7	45.0	−0.7	45.8	45.1	−0.7	45.1	45.1	0.0	45.0	44.9	−0.1	45.0	44.9	*−0.1*	45.0	45.0	0.0
15	36.0	36.3	*+0.3*	37.0	36.7	*−0.3*	37.0	37.0	*0.0*	36.7	36.9	*+0.2*	36.8	37.0	+0.2	36.8	36.7	*−0.1*	36.0	36.0	0.0
16	34.8	34.1	−0.7	35.4	34.6	−0.8	35.5	34.6	−0.9	35.3	34.8	−0.5	35.0	34.2	−0.8	35.1	34.3	−0.8	35.0	34.8	−0.2
17	35.0	32.4	−2.6	40.3	38.4	−1.9	40.3	37.3	−3.0	36.0	33.0	−3.0	32.5	33.0	*+0.5*	35.4	32.3	−3.1	39.9	39.1	−0.8
18	35 3	32.0	−3.3	45.4	40.9	*−4.5*	45.1	39.0	*−6.1*	40.1	39.1	−1.0	41.2	39.3	−1.9	39.8	33.4	*−6.4*	46.0	44.9	−1.1
19	33.0	28.2	*−4.8*	36.8	32.6	−4.2	36.3	32.0	−4.3	36.6	31.0	−5.6	38.6	32.3	−6.3	37.8	32.1	−5.7	37.3	35.0	−2.3
20	*21.4*	*18.0*	−3.4	*25.3*	*21.3*	−4.0	*25.1*	*20.0*	−5.1	*21.6*	19.3	−2.3	24.8	*17.8*	*−7.0*	*21.3*	*18.9*	−2.4	26.8	23.8	*−3.0*
21	23.2	21.0	−2.2	25.7	22.8	−2.9	25.4	22.3	−3.1	22.2	*17.0*	−5.2	*24.5*	19.8	−4.7	23.7	22.0	−1.7	*25.3*	*23.0*	−2.3
22	43.8	44.0	+0.2	44.3	44.0	*−0.3*	44.5	44.2	−0.3	44.5	42.0	−2.5	44.1	43.0	−1.1	44.0	43.9	*−0.1*	44.1	44.2	*+0.1*
23	43.8	43 9	+0.1	44.3	43.9	−0.4	44.2	44.0	−0.2	44.0	43.7	−0.3	44.1	44.0	−0.1	a44.2	a43.9	−0.3	44.0	44.0	0.0
24	42.5	40.2	−2.3	43.8	41.3	−2.5	43.5	42.0	−1.5	40.3	34.0	−6.3	43.3	39.3	−4.0	a42.9	a40.0	−2.9	43.4	41.8	−1.6
25	44.8	44.0	−0.8	45.3	44.0	−1.3	45.2	44.1	−1.1	45.0	43.8	−1.2	45.0	43.9	−1.1	a44.9	a44.0	−0.9	44.6	44.0	−0.6
26	45.0	45.2	+0.2	45.5	45.2	*−0.3*	45.7	45.2	−0.5	45.2	45.0	−0.2	45.2	45.0	−0.2	a45.2	a45.0	−0.2	45.1	45.1	0.0
27	(b)	(b)		(b)	(b)		(b)	(b)		(b)	(b)		(b)	(b)		(b)	(b)		(b)	(b)	
28	(b)	(b)		(b)	(b)		(b)	(b)		(b)	(b)		(b)	(b)		(b)	(b)		(b)	(b)	
29	34.0	29.8	−4.2	38.0	34.9	−3.1	37.2	32.5	−4.7	36.0	29.3	*−6.7*	38.5	34.7	−3.8	36.0	30.8	−5.2	38.8	36.3	−2.5
30	38.9	36.0	−2.9	44.7	41.1	−3.6	43.8	39.5	−4.3	40.4	36.0	−4.4	43.0	39.0	−4.0	40.9	37.0	−3.9	44.0	42.3	−1.7
31	46.5	45.0	−1.5	48.0	45.8	−2.2	47.8	45.9	−1.9	47.6	45.9	−1.7	47.9	45.4	−2.5	a47.2	a45.4	−1.8	47.6	46.8	−0.8
Means	38.9	37.2	−1.7	41.4	39.3	−2.1	41.2	38.8	−2.4	39.7	37.2	−2.5	40.4	38.0	−2.4	39.9	37.6	−2.3	41.2	40.1	−1.1

a Affected by water. b Under water.

Station 2 Sphagnum moss.
Station 3. Newly sanded, thinly vined.
Station 4. Newly sanded, heavily vined.
Station 5. Peat with moss, heavily vined.
Station 6. Old sanded, heavily vined.
Station 7. Scalped piece, bare peat.
Station 9. Sandy loam on upland.

Highest and lowest readings are in italics. Means are for 18 days.

TABLE 1.—MINIMUM TEMPERATURES IN SHELTER AND IN OPEN AT 5-INCH HEIGHT, FOR EACH STATION, TOGETHER WITH THE DIFFERENCE BETWEEN READINGS, MATHER, WIS., 1907—Continued.

Day of month.	Station 2.			Station 3.			Station 4.			Station 5.			Station 6.			Station 7.			Station 9.		
	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.
JUNE.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	31.7	*27.9*	−3.8	34.9	*31.0*	−3.9	34.9	*30.5*	−4.4	31.4	*26.2*	−5.2	36.0	35.3	−0.7	34.5	28.7	*−5.8*	34.5	32.2	−2.3
2	32.3	29.4	−2.9	37.0	34.0	−3.0	36.1	33.0	−3.1	31.4	27.9	−3.5	35.0	29.8	−5.2	34.8	30.7	−4.1	36.2	32.8	*−3.4*
3	54.0	53.0	−1.0	54.9	52.3	−2.6	54.8	51.0	−3.8	53.6	46.9	−6.7	53.5	47.0	*−6.5*	53.5	50.0	−3.5	55.1	53.8	−1.3
4	38.4	35.2	−3.2	42.7	39.6	−3.1	41.8	39.0	−2.8	40.2	35.0	−5.2	40.3	36.5	−3.8	40.3	36.6	−3.7	41.6	40.4	−1.2
5	41.8	38.0	−3.8	43.9	39.7	*−4.2*	43.5	41.4	−2.1	43.3	41.5	−1.8	44.0	41.5	−2.5	43.3	41.5	−1.8	43.8	42.9	−0.9
6	*31.4*	*27.9*	−3.5	[a]34.0	[a]31.3	−2.7	[a]*33.4*	[a]30.7	−2.7	[a]*30.7*	[a]26.8	−3.9	[a]*32.0*	[a]*28.2*	−3.8	*31.1*	*27.1*	−4.0	*33.0*	*31.5*	−1.5
7	47.0	44.8	−2.2	47.9	47.5	*−0.4*	47.7	46.0	−1.7	47.0	43.8	−3.2	47.7	44.0	−3.7	47.5	45.1	−2.4	47.3	46.6	−0.7
8	*31.4*	*27.9*	−3.5	35.0	32.2	−2.8	35.1	32.0	−3.1	30.8	26.5	−4.3	34.3	29.4	−4.9	31.4	27.9	−3.5	33.5	31.8	−1.7
9	35.9	32.5	−3.4	40.0	37.4	−2.6	39.9	35.2	*−4.7*	35.1	30.5	−4.6	38.3	33.9	−4.4	36.0	32.0	−4.0	39.2	37.9	−1.3
10	53.9	53.3	*−0.6*	54.6	53.2	−1.4	54.6	53.2	−1.4	54.0	53.0	*−1.0*	54.3	52.9	−1.4	53.9	53.0	*−0.9*	54.5	53.4	−1.1
11	44.1	39.1	−5.0	46.2	42.2	−4.0	45.5	41.7	−3.8	44.2	38.4	−5.8	45.2	40.7	−4.5	44.8	40.1	−4.7	46.0	43.7	−2.3
12	51.2	50.5	−0.7	53.0	51.0	−2.0	52.9	52.1	*−0.8*	52.5	51.0	−1.5	52.3	50.2	−2.1	53.0	51.4	−1.6	53.0	52.5	*−0.5*
13	37.3	34.4	−2.9	42.6	39.6	−3.0	42.3	39.1	−3.2	36.2	32.4	−3.8	39.4	34.8	−4.6	37.3	33.6	−3.7	42.9	41.1	−1.8
14	35.0	31.0	−4.0	39.9	37.9	−2.0	39.4	36.3	−3.1	33.8	29.6	−4.2	33.0	33.0	*0.0*	34.6	31.1	−3.5	37.5	36.1	−1.6
15	38.7	35.0	−3.7	42.0	39.3	−2.7	41.4	39.0	−2.4	37.6	34.0	−3.6	39.5	36.1	−3.4	38.0	34.8	−3.2	42.0	41.0	−1.0
16	48.6	46.0	−2.6	54.0	51.2	−2.8	52.9	50.2	−2.7	48.9	45.5	−3.4	50.4	46.8	−3.6	49.5	46.6	−2.9	53.8	52.0	−1.8
17	*66.0*	*62.9*	−3.1	*69.0*	*65.8*	−3.2	*69.1*	*65.4*	−3.7	*68.5*	*62.5*	−6.0	*68.0*	*64.0*	−4.0	*69.0*	*65.9*	−3.1	*68.0*	*66.5*	−1.5
18	52.5	49.6	−2.9	58.0	55.2	−2.8	56.9	54.9	−2.0	52.7	48.9	−3.8	55.0	50.6	−4.4	55.0	51.0	−4.0	57.3	55.7	−1.6
19	50.2	46.8	−3.4	56.2	53.3	−2.9	55.8	52.5	−3.3	53.4	48.7	−4.7	53.4	47.5	−5.9	54.0	49.3	−4.7	56.1	54.9	−1.2
20	45.2	42.3	−2.9	51.0	48.0	−3.0	49.8	47.5	−2.3	51.0	42.4	*−8.6*	47.8	43.4	−4.4	46.0	42.2	−3.8	50.1	47.9	−2.2
21	45.0	41.4	−3.6	49.3	46.5	−2.8	48.8	46.1	−2.7	44.0	40.3	−3.7	46.8	42.4	−4.4	45.0	41.8	−3.2	48.6	46.6	−2.0
22	61.2	59.0	−2.2	61.8	60.4	−1.4	61.5	60.1	−1.4	61.1	59.6	−1.5	61.1	59.1	−2.0	61.1	59.8	−1.3	61.7	60.6	−1.1
23	58.0	53.9	−4.1	60.0	57.7	−2.3	59.9	57.1	−2.8	59.0	55.2	−3.8	60.0	56.3	−3.7	59.2	56.0	−3.2	59.8	57.5	−2.3
24	53.9	49.6	−4.3	56.0	53.8	−2.2	55.2	53.0	−2.2	52.5	49.5	−3.0	53.9	50.8	−3.1	53.4	49.6	−3.8	54.1	53.2	−0.9
25	55.9	53.3	−2.6	57.9	56.3	−1.6	57.4	55.9	−1.5	55.9	53.1	−2.8	56.2	53.2	−3.0	56.2	53.5	−2.7	57.5	56.5	−1.0
26	46.0	40.9	*−5.1*	48.1	46.1	−2.0	47.9	46.0	−1.9	47.8	45.7	−2.1	48.3	43.8	−4.5	48.0	46.0	−2.0	48.1	47.2	−0.9
27	39.3	35.2	−4.1	44.5	42.0	−2.5	43.4	40.9	−2.5	39.2	34.0	−5.2	40.8	35.1	−5.7	38.2	35.0	−3.2	44.5	42.8	−1.7
28	41.2	36.7	−4.5	44.3	41.1	−3.2	43.8	41.0	−2.8	38.6	35.2	−3.4	40.5	37.5	−3.0	39.8	36.8	−3.0	43.9	42.1	−1.8
29	44.8	42.6	−2.2	51.4	48.9	−2.5	50.0	48.0	−2.0	44.6	41.1	−3.5	47.8	42.8	−5.0	46.1	43.0	−3.1	51.1	49.8	−1.3
30	51.3	48.9	−2.4	56.9	54.1	−2.8	55.5	53.0	−2.5	51.0	47.4	−3.6	54.2	48.7	−5.5	53.1	49.4	−3.7	56.8	54.1	−2.7
Means	45.4	42.3	−3.1	48.9	46.3	−2.6	48.4	45.7	−2.7	45.7	41.8	−3.9	47.0	43.2	−3.8	46.3	43.0	−3.3	48.4	46.8	−1.6

[a] Affected by water.

Station 2. Sphagnum moss.
Station 3. Newly sanded, thinly vined.
Station 4. Newly sanded, heavily vined.
Station 5. Peat with moss, heavily vined.
Station 6. Old sanded, heavily vined.
Station 7. Scalped piece, bare peat.
Station 9. Sandy loam on upland.

Highest and lowest readings are in italics.

TABLE 1.—MINIMUM TEMPERATURES IN SHELTER AND IN OPEN AT 5-INCH HEIGHT, FOR EACH STATION, TOGETHER WITH THE DIFFERENCE BETWEEN READINGS, MATHER, WIS., 1907—Continued.

Day of month.	Station 2.			Station 3.			Station 4.			Station 5.			Station 6.			Station 7.			Station 9.		
	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.
JULY.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	55.0	52.0	−3.0	58.8	57.1	−1.7	58.5	57.0	−1.5	58.8	55.9	−2.9	58.7	54.3	−4.4	59.0	58.1	−0.9	59.0	57.8	−1.2
2	*32.4*	*29.4*	−3.0	*38.4*	*34.8*	−3.6	*37.4*	*34.3*	−3.1	*31.2*	*27.9*	−3.3	*35.2*	*29.0*	−6.2	*33.0*	*29.7*	−3.3	*36.9*	*33.9*	*−3.0*
3	41.4	38.5	−2.9	48.0	45.0	−3.0	47.1	44.7	−2.4	40.2	36.2	−4.0	44.1	38.3	−5.8	43.0	39.2	−3.8	47.7	45.0	−2.7
4	47.3	44.7	−2.6	51.6	48.9	−2.7	50.8	48.8	−2.0	50.8	43.9	−6.9	49.9	46.0	−3.9	47.4	45.0	−2.4	51.0	49.5	−1.5
5	60.6	59.4	−1.2	61.3	60.3	−1.0	61.2	60.5	−0.7	60.8	59.7	−1.1	61.0	61.5	*+0.5*	[a]57.5	[a]54.7	−2.8	61.0	60.0	−1.0
6	55.0	52.8	−2.2	59.0	57.0	−2.0	58.0	56.2	−1.8	54.8	52.0	−2.8	56.8	52.1	−4.7	[a]55.5	[a]52.1	−2.8	58.2	57.3	−0.9
7	46.3	43.2	−3.1	51.2	48.0	−3.2	50.8	48.0	−2.8	50.8	42.5	−8.3	49.0	43.7	−5.3	48.9	46.3	−2.6	50.4	49.0	−1.4
8	50.0	47.0	−3.0	56.9	53.1	−3.8	55.0	50.4	*−4.6*	54.3	49.4	−4.9	55.8	50.0	−5.8	57.0	53.4	−3.6	58.1	56.2	−1.9
9	54.1	51.0	−3.1	61.0	57.1	−3.9	60.0	56.1	−3.9	56.6	51.9	−4.7	57.5	51.4	−6.1	56.9	52.5	−4.4	60.4	59.9	−0.5
10	45.2	42.3	−2.9	50.8	47.8	−3.0	49.8	47.7	−2.1	50.9	41.0	*−9.9*	47.0	42.2	−4.8	45.9	42.2	−3.7	50.0	47.6	−2.4
11	59.8	60.2	*+0.4*	60.6	60.3	*−0.3*	60.8	60.0	−0.8	61.1	60.1	*−1.0*	61.5	59.9	−1.6	61.0	60.1	−0.9	61.0	60.1	−0.9
12	44.5	42.3	−2.2	49.5	46.5	−3.0	48.4	46.1	−2.3	46.2	39.9	−6.3	46.3	41.8	−4.5	45.0	41.5	−3.5	49.2	47.0	−2.2
13	47.0	44.3	−2.7	53.0	50.0	−3.0	51.6	49.2	−2.4	48.4	44.0	−4.4	51.3	45.9	−5.4	49.9	45.9	−4.0	52.0	49.4	−2.6
14	60.9	56.4	−4.5	62.2	59.0	−3.2	62.0	59.1	−1.9	61.2	56.8	−4.4	61.5	56.8	−4.7	61.3	58.2	−3.1	62.0	60.0	−2.0
15	*68.0*	*67.8*	−0.2	*68.3*	*67.8*	−0.5	*68.1*	*67.8*	*−0.3*	*68.2*	*67.1*	−1.1	*68.0*	*66.7*	−1.3	*68.0*	*68.2*	*+0.2*	*68.1*	*68.0*	*−0.1*
16	49.3	46.3	−3.0	53.1	50.0	−3.1	52.2	50.0	−2.2	51.1	45.3	−5.8	54.4	46.5	*−7.9*	48.9	46.1	−2.8	51.7	50.4	−1.3
17	48.3	45.0	−3.3	55.1	51.3	−3.8	52.1	49.0	−3.1	50.0	45.0	−5.0	53.2	47.3	−5.9	54.0	47.9	*−6.1*	56.0	53.9	−2.1
18	46.9	44.5	−2.4	51.0	47.6	−3.4	50.1	47.8	−2.3	45.8	42.6	−3.2	47.9	43.8	−4.1	46.0	43.1	−2.9	50.2	49.0	−1.2
19	52.8	51.8	−1.0	57.1	54.8	−2.3	56.8	54.8	−2.0	53.9	51.0	−2.9	56.0	51.5	−4.5	54.1	51.6	−2.5	56.8	55.1	−1.7
20	52.9	50.1	−2.8	59.8	56.7	−3.1	59.0	55.1	−3.9	56.2	51.3	−4.9	58.0	52.5	−5.5	58.6	56.2	−2.4	60.3	58.9	−1.4
21	62.0	60.2	−1.8	65.0	63.2	−1.8	64.8	63.0	−1.8	62.2	59.9	−2.3	63.0	60.0	−3.0	62.8	61.1	−1.7	64.8	64.0	−0.8
22	60.0	57.3	−2.7	63.5	62.0	−1.5	63.2	61.4	−1.8	64.0	61.9	−2.1	64.5	62.3	−2.2	[a]61.3	[a]58.5	−2.8	63.9	63.0	−0.9
23	54.0	48.9	*−5.1*	53.2	50.1	−3.1	52.2	48.8	−3.4	[a]50.3	[a]45.9	−4.4	[a]51.0	[a]46.7	−4.3	[a]50.1	[a]47.3	−2.8	52.1	49.9	−2.2
24	61.0	58.7	−2.3	64.0	60.0	*−4.0*	64.0	59.8	−4.2	[a]61.5	[a]57.1	−4.4	[a]62.2	[a]57.9	−4.3	[a]61.3	[a]58.5	−2.8	65.0	63.1	−1.9
25	52.8	49.5	−3.3	53.7	50.9	−2.8	53.0	50.8	−2.2	[a]50.1	[a]45.7	−4.4	[a]50.8	[a]46.5	−4.3	[a]49.9	[a]47.1	−2.8	53.0	51.6	−1.4
26	46.3	42.3	−4.0	49.4	47.0	−2.4	48.5	46.3	−2.2	[a]46.5	[a]42.1	−4.4	[a]47.2	[a]42.9	−4.3	[a]46.3	[a]43.5	−2.8	49.0	47.8	−1.2
27	44.9	41.0	−3.9	46.9	43.4	−3.5	45.9	43.0	−2.9	45.0	40.0	−5.0	[a]43.2	[a]38.9	−4.3	[a]42.3	[a]39.5	−2.8	44.9	43.4	−1.5
28	56.6	55.3	−1.3	58.9	57.0	−1.9	59.2	56.5	−2.7	57.5	53.2	−4.3	58.4	54.0	−4.4	[a]56.2	[a]53.4	−2.8	59.0	56.9	−2.1
29	51.3	48.1	−3.2	56.1	54.0	−2.1	55.9	53.2	−2.7	55.0	51.5	−3.5	56.1	53.0	−3.1	56.5	55.0	−1.5	56.1	55.0	−1.1
30	46.5	45.0	−1.5	51.0	48.1	−2.9	49.9	46.4	−3.5	50.0	41.6	−8.4	48.9	43.2	−5.7	49.5	45.9	−3.6	52.0	49.9	−2.1
31	52.9	48.5	−4.4	56.1	53.1	−3.0	55.2	52.0	−3.2	54.4	50.0	−4.4	55.0	49.8	−5.2	55.3	53.0	−2.3	57.0	55.7	−1.3
Means	51.8	49.2	−2.6	55.6	53.0	−2.6	54.9	52.4	−2.5	53.1	48.8	−4.3	53.8	49.6	−4.2	53.0	50.2	−2.8	55.4	53.8	−1.6

[a] Estimated; actual readings valueless on account of reflowing or heavy rains.

Station 2. Spagnum moss.
Station 3. Newly sanded, thinly vined.
Station 4. Newly sanded, heavily vined.
Station 5. Peat with moss, heavily vined.
Station 6. Old Sanded, heavily vined.
Station 7. Scalped piece, bare peat.
Station 9. Sandy loam on upland.

Highest and lowest readings are in italics.

TABLE 1.—MINIMUM TEMPERATURES IN SHELTER AND IN OPEN AT 5-INCH HEIGHT, FOR EACH STATION, TOGETHER WITH THE DIFFERENCE BETWEEN READINGS, MATHER, WIS., 1907—Continued.

Day of month.	Station 2.			Station 3.			Station 4.			Station 5.			Station 6.			Station 7.			Station 9.		
	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.
AUGUST.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	51.7	47.0	−4.7	54.9	51.2	−3.7	53.4	49.1	−4.3	51.0	44.0	*−7.0*	51.6	45.5	−6.1	51.4	47.1	−4.3	54.9	52.8	−2.1
2	42.8	39.1	−3.7	45.3	43.3	−2.0	45.0	42.5	−2.5	44.3	40.9	−3.4	44.0	41.5	−2.5	44.8	43.0	−1.8	45.0	43.9	−1.1
3	43.1	40.0	−3.1	47.9	44.5	−3.4	47.0	43.8	−3.2	45.8	41.9	−3.9	46.0	41.8	−4.2	46.9	45.0	−1.9	46.8	46.5	−0.3
4	*36.2*	34.1	−2.1	44.9	42.1	−2.8	43.2	39.7	−3.5	*36.9*	*33.0*	−3.9	41.5	36.0	−5.5	*35.0*	*32.8*	−2.2	*38.9*	*37.7*	−1.2
5	58.9	57.9	−1.0	59.1	58.3	−0.8	59.1	58.2	−0.9	59.0	58.0	−1.0	59.0	57.5	−1.5	59.2	58.0	−1.2	59.0	58.2	−0.8
6	48.1	46.0	−2.1	53.4	51.0	−2.4	52.1	49.0	−3.1	47.9	44.8	−3.1	49.9	45.9	−4.0	48.1	45.4	−2.7	53.5	51.3	−2.2
7	51.3	48.2	−3.1	57.0	54.8	−2.2	56.4	54.0	−2.4	56.1	54.0	−2.1	56.3	53.4	−2.9	56.1	54.4	−1.7	56.7	55.1	−1.6
8	53.0	51.0	−2.0	56.0	54.0	−2.0	55.6	55.3	−0.3	52.0	50.1	−1.9	55.0	51.1	−3.9	55.0	51.5	−3.5	55.0	53.6	−1.4
9	52.0	48.9	−3.1	54.6	51.8	−2.8	54.1	51.9	−2.2	51.5	48.0	−3.5	53.4	49.0	−4.4	51.3	48.8	−2.5	53.4	51.9	−1.5
10	57.0	54.6	−2.4	60.1	58.0	−2.1	59.5	57.8	−1.7	55.8	53.0	−2.8	59.1	55.5	−3.6	57.0	54.3	−2.7	59.2	52.0	*−7.2*
11	*71.6*	*70.5*	−1.1	*71.9*	*67.4*	*−4.5*	*70.0*	*68.3*	−1.7	*71.3*	*69.0*	−2.3	*70.0*	*68.5*	−1.5	*71.8*	*69.8*	−2.0	*73.6*	*70.9*	−2.7
12	43.4	40.1	−3.3	50.4	46.7	−3.7	48.6	44.0	−4.6	45.2	41.0	−4.2	50.0	43.2	*−6.8*	48.0	42.7	*−5.3*	51.0	49.0	−2.0
13	45.6	42.0	−3.6	49.8	46.8	−3.0	48.9	45.9	−3.0	44.0	40.6	−3.4	47.0	42.0	−5.0	44.8	41.4	−3.4	49.5	47.5	−2.0
14	49.3	46.0	−3.3	53.5	50.6	−2.9	52.7	50.0	−2.7	48.3	45.0	−3.3	50.5	46.1	−4.4	49.1	46.1	−3.0	52.7	50.4	−2.3
15	53.6	49.6	−4.0	56.4	53.4	−3.0	56.0	53.0	−3.0	54.5	50.2	−4.3	55.5	51.1	−4.4	54.8	50.6	−4.2	56.1	54.0	−2.1
16	59.4	57.7	−1.7	61.7	60.3	−1.4	61.5	60.2	−1.3	61.0	58.6	−2.4	61.0	58.2	−2.8	61.3	59.3	−2.0	61.3	61.3	0.0
17	47.0	43.4	−3.6	51.1	48.6	−2.5	49.8	47.6	−2.2	42.8	43.6	*+0.8*	49.2	44.1	−5.1	48.7	44.3	−4.4	51.2	49.0	−2.2
18	51.0	47.7	−3.3	55.5	52.3	−3.2	54.2	51.5	−2.7	50.2	46.7	−3.5	54.1	48.7	−5.4	52.0	48.9	−3.1	56.0	54.2	−1.8
19	65.0	64.7	−0.3	65.0	65.0	*0.0*	65.0	64.8	*−0.2*	64.9	64.8	−0.1	64.9	64.3	−0.6	65.0	65.0	*0.0*	65.0	65.0	0.0
20	38.9	34.1	−4.8	43.3	39.8	−3.5	42.0	38.5	−3.5	40.6	34.8	−5.8	41.0	36.3	−4.7	44.8	43.5	−1.3	42.5	40.8	−1.7
21	39.8	35.7	−4.1	49.0	44.6	−4.4	47.7	43.6	−4.1	40.7	35.6	−5.1	46.8	40.4	−6.4	41.8	38.8	−3.0	46.5	44.7	−1.8
22	37.7	33.9	−3.8	*42.5*	*39.5*	−3.0	*41.4*	*38.4*	−3.0	37.5	33.6	−3.9	*40.0*	*35.3*	−4.7	39.0	35.6	−3.4	42.6	40.8	−1.8
23	51.2	47.2	−4.0	51.7	48.3	−3.4	54.5	51.1	−3.4	50.1	46.1	−4.0	51.9	47.3	−4.6	51.2	48.0	−3.2	53.5	52.4	−1.1
24	44.7	41.0	−3.7	50.9	47.6	−3.3	50.8	46.8	−4.0	49.6	44.3	−5.3	50.8	46.5	−4.3	[a]51.7	[a]49.2	−2.5	52.5	50.0	−2.5
25	38.1	*32.7*	*−5.4*	44.3	40.8	−3.5	43.4	38.7	*−4.7*	38.2	33.3	−4.9	41.2	35.6	−5.6	42.6	38.3	−4.3	46.0	44.2	−1.8
26	46.4	42.5	−3.9	50.4	47.8	−2.6	49.8	47.0	−2.8	45.0	41.0	−4.0	47.9	43.8	−4.1	48.4	44.8	−3.6	50.0	49.0	−1.0
27	55.1	56.5	*+1.4*	55.8	55.0	−0.8	55.6	55.2	−0.4	55.7	55.6	−0.1	57.5	55.6	−1.9	56.0	55.8	−0.2	55.2	57.0	*+1.8*
28	54.0	49.9	−4.1	57.0	53.4	−3.6	56.0	53.5	−2.5	54.4	50.5	−3.9	55.4	51.3	−4.1	56.0	52.6	−3.4	57.0	54.9	−2.1
29	47.6	43.7	−3.9	51.6	49.5	−2.1	51.1	48.6	−2.5	46.8	44.0	−2.8	49.6	45.3	−4.3	50.1	48.6	−1.5	51.4	50.5	−0.9
30	63.5	62.3	−1.2	63.8	63.3	−0.5	64.4	63.7	−0.7	63.7	62.6	−1.1	61.8	62.7	*+0.9*	64.0	62.1	−1.9	62.3	63.8	+1.5
31	54.9	52.4	−2.5	57.6	55.8	−1.8	57.6	55.4	−2.2	54.9	52.7	−2.2	56.5	53.5	−3.0	[a]55.7	53.8	−1.9	58.0	56.9	−1.1
Means	50.1	47.1	−3.0	53.8	51.2	−2.6	53.1	50.6	−2.5	50.3	47.1	−3.2	52.1	48.3	−3.8	51.6	49.0	−2.6	53.4	51.9	−1.5

[a] Estimated; actual readings valueless on account of reflowing or heavy rains.

Station 2. Sphagnum moss.
Station 3. Newly sanded, thinly vined.
Station 4. Newly sanded, heavily vined.
Station 5. Peat with moss, heavily vined.
Station 6. Old sanded, heavily vined.
Station 7. Scalped piece, bare peat.
Station 9. Sandy loam on upland.

Highest and lowest readings are in italics.

TABLE 1.—MINIMUM TEMPERATURES IN SHELTER AND IN OPEN AT 5-INCH HEIGHT, FOR EACH STATION, TOGETHER WITH THE DIFFERENCE BETWEEN READINGS, MATHER, WIS., 1907—Continued.

Day of month.	Station 2.			Station 3.			Station 4.			Station 5.			Station 6.			Station 7.			Station 9.		
	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.
SEPTEMBER.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	65.0	60.9	−4.1	*67.1*	63.8	*−3.3*	*67.5*	63.4	−3.1	*66.5*	61.7	−4.8	*66.6*	62.4	−4.2	*66.2*	62.8	−3.4	69.6	*66.7*	−2.9
2	47.0	41.9	−5.1	52.9	50.4	−2.5	52.3	49.6	−2.7	50.0	45.5	−4.5	50.6	45.7	−4.9	51.5	49.1	−2.4	52.6	51.4	−1.2
3	45.1	40.5	−4.6	50.2	47.9	−2.3	49.5	46.0	−3.5	47.0	41.3	*−5.7*	47.7	42.5	−5.2	49.5	46.4	−3 1	50.1	48.9	−1.2
4	45.1	44.7	−0.4	53.4	51.0	−2.4	52.7	50.0	−2.7	52.1	48.8	−3.3	52.9	50.6	−2.3	52.5	51.5	−1.0	52.7	52.0	−0.7
5	40.9	35.5	−5.4	44.5	43.0	−1.5	43.9	42.8	−1.1	43.4	41.3	−2.1	44.0	42.3	−1.7	43.0	39.4	−3.6	43.8	43.6	−0.2
6	38.0	33.4	−4.6	41.0	37.9	−3.1	40.7	38.2	−2.5	35.7	32.6	−3.1	38.6	34.9	−3.7	37.1	34.5	−2.6	40.9	39.4	−1.5
7	55.8	54.9	−0.9	55.5	55.7	*+0.2*	55.8	55.9	+0.1	55.9	55.5	*−0.4*	55.9	55.5	−0.4	55.9	55.6	−0.3	55.0	55.6	*+0.6*
8	55.9	55.6	*−0.3*	56.7	56.6	−0.1	56.0	56.6	*+0.6*	a53.6	a50.8	−2.8	56.7	56.4	−0.3	56.7	56.8	+0.1	56.7	56.7	0.0
9	36.5	30.3	−6.2	39.8	37.1	−2.7	39.7	35.6	*−4.1*	36.0	33.7	−2.3	39.5	34.4	−5.1	39.5	37.4	−2.1	39.5	38.4	−1.1
10	35.5	30.3	−5.2	a37.8	a35.3	−2.5	a37.2	a35.2	−2.0	a35.1	a32.3	−2.8	a36.4	a33.2	−3.2	33.9	31.6	−2.3	38.2	36.8	−1.4
11	42.2	37.4	−4.8	45.6	43.3	−2.3	44.6	42.3	−2.3	41.0	36.5	−4.5	42.6	38.7	−3.9	43.2	38.9	−4.3	46.5	45.4	−1.1
12	40.5	36.6	−3.9	44.6	42.2	−2.4	43.3	40.2	−3.1	40.5	37.0	−3.5	43.4	38.4	−5.0	39.5	37.0	−2.5	46.3	44.8	−1.5
13	44.0	40.3	−3.7	47.0	46.1	−0.9	46.6	43.8	−2.8	43.3	39.7	−3.6	45.6	41.7	−3.9	44.6	41.1	−3.5	48.0	46.3	−1.7
14	59.4	57.3	−2.1	59.7	57.4	−2.3	60.1	57.3	−2.8	59.5	54.9	−4.6	59.7	54.8	−4.9	59.3	54.0	*−5.3*	57.0	57.4	+0.4
15	58.0	53.6	−4.4	60.1	57.3	−2.8	59.7	56.6	−3.1	56.9	53.0	−3.9	58.7	54.8	−3.9	58.3	55.1	−3.2	60.0	57.5	*−2.5*
16	*65.5*	*64.2*	−1.3	65.8	*64.8*	−1.0	66.0	*64.8*	−1.2	65.6	*64.5*	−1.1	65.5	*64.4*	−1.1	65.6	*64.8*	−0.8	*65.4*	64.8	−0.6
17	47.6	43.6	−4.0	52.5	49.5	−3.0	51.7	48.9	−2.8	46.8	43.5	−3.3	49.0	44.0	−5.0	48.0	44.8	−3.2	52.3	50.4	−1.9
18	57.9	56.0	−1.9	58.3	57.8	−0.5	58.4	57.6	−0.8	58.0	56.1	−1.9	58.0	57.8	*−0.2*	58.1	58.3	*+0.2*	58.0	57.7	−0.3
19	60.6	58.0	−2.6	61.1	59.6	−1.5	61.0	59.6	−1.4	60.8	58.8	−2.0	60.7	58.8	−1.9	60.6	59.5	−1.1	60.6	59.9	−0.7
20	58.8	57.2	−1.6	59.5	56.7	−2.8	59.2	57.3	−1.9	59.2	56.2	−3.0	59.2	56.2	−3.0	59.4	57.9	−1.5	59.5	58.6	−0.9
21	35.0	29.5	−5.5	38.5	36.4	−2.1	37.5	34.0	−3.5	35.6	31.1	−4.5	36.8	31.5	−5.3	35.3	31.1	−4.2	37.6	35.3	−2.3
22	29.0	22.7	*−6.3*	a31.1	a28.6	−2.5	a30.5	a28.5	−2.0	25.2	19.7	−5.5	27.6	20.0	*−7.6*	27.0	22.7	−4.3	30.2	27.8	−2.4
23	42.8	37.0	−5.8	44.2	41.4	−2.8	43.9	40.4	−3.5	43.7	39.0	−4.7	43.9	39.3	−4.6	44.0	41.7	−2.3	43.5	42.4	−1.1
24	43.3	40.3	−3.0	43.3	42.0	−1.3	43.0	42.7	−0.3	42.7	41.7	−1.0	43.1	41.6	−1.5	43.0	42.9	−0.1	43.2	42.4	−0.8
25	25.4	19.5	−5.9	a28.0	a25.5	−2.5	a27.4	a25.4	−2.0	25.0	20.6	−4.4	25.2	20.6	−4.6	26.5	25.0	−1.5	27.6	26.3	−1.3
26	29.3	24.7	−4.6	a33.8	a31.3	−2.5	a33.2	a31.2	−2.0	26.4	22.6	−3.8	29.5	23.7	−5.8	28.8	26.0	−2.8	31.5	29.3	−2.2
27	32.1	27.0	−5.1	33.7	31.2	−2.5	33.6	31.3	−2.3	30.0	26.1	−3.9	31.3	27.4	−3.9	31.2	28.1	−3.1	33.3	31.6	−1.7
28	38.7	34.6	−4.1	39.0	37.2	−1.8	38.7	37.9	−0.8	38.5	36.9	−1.6	38.6	37.5	−1.1	38.5	37.0	−1.5	38.8	38.0	−0.8
29	28.9	24.6	−4.3	30.0	27.7	−2.3	29.7	27.4	−2.3	26.3	23.3	−3.0	28.0	24.6	−3.4	28.0	26.0	−2.0	29.8	28.6	−1.2
30	*25.1*	*18.8*	*−6.3*	*26.6*	*23.4*	−3.2	*26.0*	*22.4*	−3.6	*21.7*	*16.6*	−5.1	*24.6*	*18.1*	−6.5	*24.0*	*20.5*	−3.5	*26.7*	*24.7*	−2.0
Means	44.3	40.4	−3.9	46.7	44.6	−2.1	46.3	44.1	−2.2	44.1	40.7	−3.4	45.3	41.7	−3.6	45.0	42.6	−2.4	46.5	45.3	−1.2

a Estimated; actual readings valueless on account of reflowing or heavy rains.

Station 2. Sphagnum moss.
Station 3. Newly sanded, thinly vined.
Station 4. Newly sanded, heavily vined.
Station 5. Peat with moss, heavily vined.
Station 6. Old sanded, heavily vined.
Station 7. Scalped piece, bare peat.
Station 9. Sandy loam, on upland.

Highest and lowest readings are in italics.

TABLE 1.—MINIMUM TEMPERATURES IN SHELTER AND IN OPEN AT 5-INCH HEIGHT, FOR EACH STATION, TOGETHER WITH THE DIFFERENCE BETWEEN READINGS, MATHER, WIS., 1907—Continued.

Day of month.	Station 2.			Station 3.			Station 4.			Station 5.			Station 6.			Station 7.			Station 9.		
	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.	Shelter.	Exposed.	Difference.
OCTOBER.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	31.5	26.6	−4.9	33.0	30.0	−3.0	33.2	29.8	−3.4	29.5	25.6	−3.9	32.0	26.9	−5.1	31.5	28.5	−3.0	34.0	32.3	−1.7
2	*49.3*	*45.1*	−4.2	*51.2*	*46.6*	−4.6	*52.2*	*48.8*	−3.4	*52.0*	*46.7*	−5.3	*52.5*	*47.5*	−5.0	*51.9*	*48.0*	−3.9	*52.0*	*50.0*	−2.0
3	39.7	35.7	−4.0	43.4	41.2	−2.2	42.7	40.4	−2.3	39.0	35.5	−3.5	41.4	36.8	−4.6	43.2	38.0	−5.2	44.8	43.6	−1.2
4	32.5	27.3	−5.2	38.5	34.0	−4.5	36.5	32.5	−4.0	33.3	29.5	−3.8	35.3	29.3	−6.0	35.5	30.5	−5.0	40.0	38.4	−1.6
5	32.7	27.0	−5.7	38.3	35.1	−3.2	37.5	33.7	−3.8	34.8	30.3	−4.5	35.1	28.7	−6.4	35.3	31.7	−3.6	40.3	39.0	−1.3
6	38.6	33.7	−4.9	42.4	38.6	−3.8	41.5	38.1	−3.4	41.4	35.6	−5.8	43.9	39.0	−4.9	40.6	37.0	−3.6	43.8	41.8	−2.0
7	41.3	37.4	−3.9	45.5	42.7	−2.8	44.5	41.4	−3.1	41.6	38.0	−3.6	44.3	39.5	−4.8	42.7	40.3	−2.4	47.3	45.3	−2.0
8	21.2	15.9	-5.3	22.7	19.5	−3.2	21.8	17.7	−4.1	18.8	12.8	−6.0	20.1	14.6	−5.5	21.5	17.5	−4.0	22.5	19.8	−2.7
9	39.0	32.8	−6.2	38.4	35.4	−3.0	40.0	34.8	−5.2	40.5	34.0	−6.5	40.7	34.9	−5.8	40.0	37.7	−2.3	39.6	37.5	−2.1
10	28.9	25.0	−3.9	31.7	28.4	−3.3	31.4	27.0	−4.4	31.4	24.8	−6.6	32.5	26.5	−6.0	31.4	28.1	−3.3	33.0	31.5	−1.5
11	32.5	26.0	*−6.5*	35.0	31.0	−4.0	34.6	29.7	−4.9	30.6	28.3	−2.3	33.4	28.5	−4.9	34.4	29.5	−4.9	34.7	33.7	−1.0
12	27.5	22.7	4.8	29.4	27.6	−1.8	28.8	26.7	−2.1	28.2	25.9	−2.3	28.6	26.2	−2.4	28.6	26.4	−2.2	29.0	28.0	−1.0
13	21.0	15.8	5.2	21.7	19.5	−2.2	21.6	16.9	−4.7	17.5	12.0	−5.5	19.0	13.0	−6.0	20.0	16.0	−4.0	23.0	21.6	−1.4
14	20.3	15.6	−4.7	20.4	17.8	−2.6	19.8	16.8	−3.0	16.0	12.4	−3.6	19.5	14.0	−5.5	20.4	17.0	−3.4	21.0	18.9	−2.1
15	43.4	39.4	−4.0	43.5	41.4	−2.1	43.6	42.3	−1.3	43.0	41.5	−1.5	43.7	42.0	−1.7	43.0	41.7	−1.3	43.4	42.6	−0.8
16	34.0	29.4	−4.6	36.3	34.3	−2.0	35.7	33.2	−2.5	33.5	29.4	−4.1	35.0	32.3	−2.7	34.5	32.6	−1.9	35.8	35.5	−0.3
17	30.5	27.4	-3.1	33.4	30.7	−2.7	32.6	29.4	−3.2	31.5	28.4	−3.1	33.7	29.6	−4.1	32.8	30.8	−2.0	35.6	34.2	−1.4
18	22.7	17.6	-5.1	24.5	21.5	−3.0	23.6	20.0	−2.6	23.3	20.7	−2.6	22.7	22.5	*−0.2*	23.8	22.6	−1.2	23.6	23.0	−0.6
19	23.0	17.9	5.1	23.3	19.6	−3.7	22.4	16.5	−5.9	18.4	13.8	−4.6	21.1	15.4	−5.7	21.7	19.0	−2.7	25.5	23.0	−2.5
20	26.8	21.9	4.9	27.3	24.6	−2.7	26.6	24.7	−1.9	26.3	23.5	−2.8	26.6	24.8	−1.8	26.5	24.5	−2.0	27.1	25.8	−1.3
21	17.7	13.2	−4.5	18.6	15.4	−3.2	18.4	13.8	−4.6	14.0	9.8	−4.2	17.0	12.5	−4.5	17.3	14.6	−2.7	17.5	15.6	−1.9
22	35.4	30.7	−4.7	36.0	32.3	−3.7	35.7	29.4	*−6.3*	34.3	26.5	*−7.8*	35.7	28.0	*−7.7*	34.6	29.3	*−5.3*	38.3	35.7	−2.6
23	26.9	21.9	-5.0	26.6	23.6	−3.0	26.0	21.0	−5.0	23.6	18.8	−4.8	25.7	20.3	−5.4	25.8	22.7	−3.1	28.5	26.6	−1.9
24	23.3	17.7	−5.6	24.7	21.4	−3.3	24.7	19.3	−5.4	18.8	14.7	−4.1	21.6	16.0	−5.6	22.4	19.0	−3.4	25.7	23.2	−2.5
25	23.5	17.2	-6.3	25.8	22.4	−3.4	25.3	21.7	−3.6	25.0	21.5	−3.5	26.0	22.0	−4.0	26.7	25.6	−1.1	26.5	25.3	−1.2
26	18.0	12.5	−5.5	17.6	14.4	−3.2	18.0	13.1	−4.9	13.7	9.3	−4.4	17.5	11.7	−5.8	18.0	13.7	−4.3	16.5	14.8	−1.7
27	32.5	29.4	−3.1	34.0	31.7	−2.3	33.7	31.4	−2.3	32.6	31.6	−1.0	33.7	31.6	−2.1	33.4	31.9	−1.5	33.7	33.2	−0.5
28	*15.8*	*10.0*	−5.8	*16.7*	*13.5*	−3.2	*16.0*	*10.7*	−5.3	*11.0*	*6.4*	−4.6	*14.3*	*8.6*	−7.7	*14.0*	*11.8*	−2.2	*15.4*	*13.6*	−1.8
29	29.3	25.7	−3.6	27.7	23.5	−4.2	28.4	22.3	−6.1	29.1	21.7	−7.4	29.6	22.8	−6.8	30.3	25.8	−4.5	31.0	29.0	−2.0
30	36.5	34.8	*−1.7*	36.7	36.0	*−0.7*	36.8	36.2	*−0.6*	36.6	35.7	*−0.9*	36.5	36.3	*−0.2*	36.5	36.1	*−0.4*	36.6	36.7	*+0.1*
31	33.8	29.4	−4.4	34.0	29.3	*−4.7*	35.0	31.1	−3.9	34.5	29.5	−5.0	35.3	28.8	−4.5	35.0	30.5	−4.5	35.5	34.3	−1.2
Means	30.0	25.2	−4.8	31.6	28.5	−3.1	31.2	27.4	−3.8	29.2	25.0	−4.2	30.8	26.1	−4.7	30.8	27.7	−3.1	32.3	30.8	−1.5

Station 2. Sphagnum moss.
Station 3. Newly sanded, thinly vined.
Station 4. Newly sanded, heavily vined.
Station 5. Peat with moss, heavily vined.
Station 6. Old sanded, heavily vined.
Station 7. Scalped piece, bare peat.
Station 9. Sandy loam on upland.

Highest and lowest readings are in italics.

TABLE 1a.—MONTHLY AND SEASONAL MEANS OF MINIMUM TEMPERATURES IN SHELTER AND IN OPEN AT 5-INCH HEIGHT, WITH DIFFERENCE BETWEEN THE READINGS, MATHER, WIS., 1907.

	May.[a]	June.	July.	Aug.	Sept.	Oct.	Means.[b]
	°	°	°	°	°	°	°
Station 2:							
Shelter	38.9	45.4	51.8	50.1	44.3	30.0	43.4
Exposed	37.2	42.3	49.2	47.1	40.4	25.2	40.2
Difference	−1.7	−3.1	−2.6	−3.0	−3.9	−4.8	−3.2
Station 3:							
Shelter	41.4	48.9	55.6	53.8	46.7	31.6	46.3
Exposed	39.3	46.3	53.0	51.2	44.6	28.5	43.8
Difference	−2.1	−2.6	−2.6	−2.6	−2.1	−3.1	−2.5
Station 4:							
Shelter	41.2	48.4	54.9	53.1	46.3	31.2	45.8
Exposed	38.8	45.7	52.4	50.6	44.1	27.4	43.2
Difference	−2.4	−2.7	−2.5	−2.5	−2.2	−3.8	−2.6
Station 5:							
Shelter	39.7	45.7	53.1	50.3	44.1	29.2	43.7
Exposed	37.2	41.8	48.8	47.1	40.7	25.0	40.1
Difference	−2.5	−3.9	−4.3	−3.2	−3.4	−4.2	−3.6
Station 6:							
Shelter	40.4	47.0	53.8	52.1	45.3	30.8	44.9
Exposed	38.0	43.2	49.6	48.3	41.7	26.1	41.2
Difference	−2.4	−3.8	−4.2	−3.8	−3.6	−4.7	−3.7
Station 7:							
Shelter	39.9	46.3	53.0	51.6	45.0	30.8	44.4
Exposed	37.6	43.0	50.2	49.0	42.6	27.7	41.7
Difference	−2.3	−3.3	−2.8	−2.6	−2.4	−3.1	−2.7
Station 9:							
Shelter	41.2	48.4	55.4	53.4	46.5	32.3	46.2
Exposed	40.1	46.8	53.8	51.9	45.3	30.8	44.8
Difference	−1.1	−1.6	−1.6	−1.5	−1.2	−1.5	−1.4

[a] Means for eighteen days.

[b] Mean difference all stations, −2.8°.

Station 2. Sphagnum moss.
Station 3. Newly sanded, thinly vined.
Station 4. Newly sanded, heavily vined.
Station 5. Peat with moss, heavily vined
Station 6. Old sanded, heavily vined.
Station 7. Scalped piece, bare peat.
Station 9. Sandy loam on upland.

Readings of exposed minimum thermometers at the surface and at the 5-inch height.—It was found impracticable to place thermometers in the shelters at a lower elevation than 5 inches above the surface of the ground, and consequently readings of instruments exposed at this elevation in the open were used in connection with the discussion of Tables 1 and 1*a*. Having found the difference prevailing between minimum thermometers exposed inside and outside of shelters, it seemed advisable to determine the difference between the readings of the minimum thermometers so exposed in the open and of additional instruments placed at the immediate surface. The cranberry vines extend along the surface, their uprights reaching above several inches, and readings of instruments placed at different elevations at any particular station indicate approximately the temperature which the vines and leaves experience. Again, the temperature at the immediate surface is naturally largely governed by the conditions of the soil beneath, and the readings of the surface thermometers were therefore needed in connection with the discussion of soil temperatures.

It seemed advisable, as far as practicable, to have the thermometers at the 5-inch height placed directly above the surface instruments, in order that the conditions of the soil and vegetation beneath might be the same for both exposures. This method was followed at all stations except Station 4, where, on account of the special conditions prevailing, it was found necessary to place the surface minimum on the ground a few feet distant from the instrument exposed at the 5-inch height. The vegetation over which the surface thermometer was placed at this station was more dense than at the point where the upper thermometer was exposed, referred to in the discussion of Tables 1 and 1*a*. In all cases the lower minimum thermometers rested upon the ground, although at Stations 2 and 9 they were at the same time fastened to the base of the post which supported other instruments. Were the conditions exactly the same regarding soil and vegetation over a large area at each station, a better comparison would be secured by placing the upper instrument at a point sufficiently removed from the surface thermometer so that it would not shield in the slightest degree the lower instrument, but it is most difficult to secure in a bog surface and soil conditions that are exactly similar for a considerable area. There is certain to be a variation in the character and quantity of the vegetation, and sometimes in the character of the soil, even in a small area. These varying conditions may be also considered as factors in the comparison previously made between thermometers exposed in the open and in shelters.

Space does not permit the publication of the daily readings of the two exposed minimums at the several stations, but Table 2 shows the monthly and the seasonal averages for the year 1907. The readings were generally higher at the surface than at the 5-inch height, and especially so during clear, cool nights. During cloudy and windy weather there was but little difference, and sometimes the surface instrument even registered lower. In fact, at the surface at Station 4, the average for the entire season was slightly lower at the height of 5 inches, but a satisfactory comparison was not possible at that point, for reasons given above.

There was also a complication at Station 7, in that these thermometers were placed in the middle of a scalped piece, 10 feet square, surrounded by a section of dense sphagnum moss. As stated in a previous paragraph, the instruments were exposed usually over a surface that was representative of a large section of the bog surrounding it, because the temperature naturally is affected by the surface conditions, not only at the point of exposure, but for a considerable area in the vicinity. However, at Station 7 the scalped area was only a relatively small section within an extensive field of sphagnum moss. Moreover, the soil at this station during 1907 was very damp, and the consequent evaporation affected the surface thermometer more than the one at 5 inches.

The depression of the thermometers at the 5-inch height was greatest during cold, clear nights, with comparatively high barometer and light wind, when radiation was freest, apparently for the same reason that the exposed minimums registered lower than those in shelters. (Table 1.) The moisture resulting from dew, rain, or reflowing sometimes affected the readings of the instruments, especially when water covered the bulbs of the thermometers. For instance, dew occasionally formed on the bulb of the upper thermometer when the lower was perfectly

dry, and at other times the lower thermometer remained wet from rain, the cold of evaporation sometimes lowering the readings of the instrument, especially when rain was followed in the nighttime by wind. At such times the upper thermometers were usually higher than the lower ones—an inversion of the usual conditions. Often this difference amounted to several degrees. On the other hand, water from a warm rain remaining on the bulb of a thermometer often served to raise its reading when the air remained humid and calm.

There seemed to be no uniformity in the variation from month to month, although usually the differences were greatest in October. The average depression of temperature at the 5-inch height below that at the surface for the season of 1907 was 1°. The average depression on clear, cool nights probably reached 4°. *There were several instances of differences exceeding 6°.* The greatest average monthly depression of the upper thermometers for any one month was 3°, at Station 5, in October. At Station 4 the *lower* thermometer averaged 0.4°, 0.5°, and 0.1° lower in May, June, and July, respectively, than the upper thermometer. *However, in September and October, at Station 4, the lower minimum averaged higher than the upper one by 0.1° and 0.2°, respectively, and in August there was no difference.* The lack in uniformity of the vegetation at Station 4 has been referred to above.

In the year 1906 similar data were available for Stations 3, 5, 6, 7, and 9 for the months of August and September. The average depressions of the thermometers at the 5-inch height below those at the surface for the month of August in the years, 1906 and 1907, respectively, were as follows: Station 3, 3° and 2.5°; Station 5, 1.6° and 1.7°; Station 6, 1.2° and 1°; Station 7, 3° and 0.2°; Station 9, 0.6° and 0.7°; for the month of September, 1906 and 1907: Station 3, 4.7° and 1.3°; Station 5, 2.4° and 2.3°; Station 6, 1.6° and 1.4°; Station 7, 4.8° and +0.3°[a]; Station 9, 1° and 0.3°.

It is not easy to state the exact reasons for these great differences in temperature. Of course, the upper thermometers were so placed that there was freer radiation from them than from those at the surface; yet it is not thought that the difference in radiation should be sufficient reason for such great differences in temperature, reaching a maximum difference of 6° and even 7° on several nights. The fact that the thermometer exposed at the surface at Station 4 averaged lower during more than half the season than the one at the 5-inch height, and that at that station the thermometers were placed several feet apart, and not one directly above the other, as at other stations, might suggest that at the remaining stations the surface thermometers generally registered higher because they were shielded by the thermometers immediately above. It is, however, difficult to believe that the very slight interposition of the upper thermometer could be responsible for differences of several degrees, as often occurred. The fact that the surface thermometer at Station 4 was located on a surface more densely covered with vegetation than the place where the upper thermometer at the same station was located should partially account for the apparent inconsistency in the readings at that station. There was so much water at Station 7 in 1907 as compared with 1906 as to seriously affect the comparison of the thermometer readings, and it is because of the great amount of evaporation in 1907 at the surface that the lower minimum averaged relatively lower than in 1906.

In a marsh grasses and uprights from the vines interfere slightly with radiation from the thermometers placed on the surface, and it is probable that a thermometer or leaf exposed at an elevation above the surface loses its heat more rapidly by radiation than if it rested upon the surface, because the upper one is not shielded in any way, and while the radiation is going on from the lower one, at the same time heat is being conducted to it from the ground beneath. A thermometer resting upon the surface of the bog becomes a part of the soil or vegetation upon which it rests, as it were, and is benefited by the free conduction of heat to it from the ground, while the conduction to and through the air is very slight in comparison; because of these differences in radiation and conduction, the surface thermometer usually registers a higher temperature than the instrument a few inches above. For the same reason, the temperature of the vegetation at the surface and 5 inches above would vary as these temperatures have varied,

[a] Surface instrument registered lower.

especially when the surface vegetation is shielded by vegetation above. It is a matter of common knowledge that in the bogs the cranberries growing at the tops of the uprights a few inches above the ground are often damaged by frost, while those lying on or near the ground escape injury.

The readings of exposed minimum thermometers at a number of different elevations will be discussed in detail later in connection with Tables 13 and 14, in order to show approximately the height above the ground at which the lowest minimum occurs.

Table 2.—Monthly and Seasonal Means of Minimum Temperatures in Open at Surface and at 5-inch Height, with Difference Between the Readings, Mather, Wis., 1907.

	May.[a]	June.	July.	Aug.	Sept.	Oct.	Means.[b]
	°	°	°	°	°	°	°
Station 2:							
Surface	37.6	43.3	52.0	49.4	41.9	27.5	41.9
5 inch	37.2	42.3	49.2	47.1	40.4	25.2	40.2
Difference	−0.4	−1.0	−2.8	−2.3	−1.5	−2.3	−1.7
Station 3:							
Surface	40.4	48.8	55.5	53.7	45.9	28.8	45.5
5 inch	39.3	46.3	53.0	51.2	44.6	28.5	43.8
Difference	−1.1	−2.5	−2.5	−2.5	−1.3	−0.3	−1.7
Station 4:							
Surface	38.4	45.2	52.3	50.6	44.2	27.6	43.1
5 inch	38.8	45.7	52.4	50.6	44.1	27.4	43.2
Difference	+0.4	+0.5	+0.1	0.0	−0.1	−0.2	+0.1
Station 5:							
Surface	37.1	43.5	49.8	48.8	43.0	28.0	41.7
5 inch	37.2	41.8	48.8	47.1	40.7	25.0	40.1
Difference	+0.1	−1.7	−1.0	−1.7	−2.3	−3.0	−1.6
Station 6:							
Surface	38.7	44.0	50.3	49.3	43.1	28.3	42.3
5 inch	38.0	43.2	49.6	48.3	41.7	26.3	41.2
Difference	−0.7	−0.8	−0.7	−1.0	−1.4	−2.0	−1.1
Station 7:							
Surface	37.6	44.0	51.2	49.2	42.3	27.9	42.0
5 inch	37.6	43.0	50.2	49.0	42.6	27.7	41.7
Difference	0.0	−1.0	−1.0	−0.2	−0.3	0.2	−0.3
Station 9:							
Surface	40.9	48.7	55.0	52.6	45.6	31.1	45.6
5 inch	40.1	46.8	53.8	51.9	45.3	30.8	44.8
Difference	−0.8	−1.9	−1.2	−0.7	−0.3	−0.3	−0.8

[a] Means for eighteen days.

[b] Mean difference all stations, 1.0°.

Station 2. Sphagnum moss.
Station 3. Newly sanded, thinly vined.
Station 4. Newly sanded, heavily vined.
Station 5. Peat with moss, heavily vined.
Station 6. Old sanded, heavily vined.
Station 7. Scalped piece, bare peat.
Station 9. Sandy loam on upland.

Observations of temperatures in soil and at the surface in different locations, Mather, Wis., 1906 and 1907.—This discussion has already shown that there is a wide difference in temperature at various points at the surface and a few inches above, in the same bog, and that the vegetation in bottom lands is subjected to temperatures of varying degree. It seemed desirable to determine what relation, if any, exists between the temperature at and near the surface and the character of the soil and its covering. Observations made at Mather, Wis., during 1906 and 1907 of soil temperatures in connection with exposed thermometers above the surface furnish interesting data bearing on this subject. The average readings are herewith given for September,

1906, for four selected stations, this being preliminary to the more extensive observations of the following year.

AVERAGE TEMPERATURES FOR SEPTEMBER, 1906, MATHER, WIS.

	Station 3.	Station 4.	Station 6.	Station 5.
	°	°	°	°
Maximum soil temperature, 3 inches	64.2	63.2	61.1	59.8
Minimum soil temperature, 3 inches	56.1	59.1	59.1	59.2
Nightly loss of soil heat, 3 inches	8.1	4.1	2.0	.6
Exposed minimum at surface	51.2	47.9	44.2	44.1

Station 3, newly sanded and thinly vined, representing best conditions of sanding, draining, and cultivating.
Station 4, newly sanded and heavily vined, representing best conditions of sanding and draining.
Station 6, old (9 years), sanded and heavily vined, stratum of peat, 1 inch in thickness, over old sand.
Station 5, uncultivated marsh, peat, and sphagnum moss, poorly drained.

The soil thermometers were placed at a depth of 3 inches, and it was found by a series of eye observations and by comparison with the soil thermograph traces that the maximum soil temperatures usually occurred at about 6 p. m. and the minimum soil temperatures at about 7 a. m. (See Fig. 20, showing average hourly soil thermograph readings at Stations 3 and 5, Mather, Wis., 1907.) The above table shows that the highest maximum soil temperatures and the lowest minimum soil temperatures at the depth of 3 inches and the highest exposed minimums occurred in the sanded sections, bare or thinly vined and well drained, while the lowest maximum soil temperatures, the highest minimum soil temperatures, and the lowest exposed minimums were found in the uncultivated marsh, which was poorly drained and had a thick growth of vegetation and sphagnum moss.

Prof. W. J. Humphreys[a] says: "The better the absorber, other things being equal, the warmer it gets during insolation and the more it heats the air, while the better the radiator it is, the colder, as a rule, it and the air adjacent become during the night. When the atmosphere is clear and dry, and therefore diathermanous, the cooling of objects and their liability to frost depends largely upon their capacity to radiate at ordinary temperatures. A good radiator under these conditions loses heat partly by radiation through the atmosphere to space. It cools rapidly, but the heat it gives off does not all go to warming the air, for, as explained, a part of it is directly lost to space. On the other hand, an object that radiates poorly gives off heat slowly, and what it does give off is in a large measure by conduction to the atmosphere. It tends to conserve both its own temperature and that of the surrounding air, and thereby diminishes the probability of frost."

As stated before, during the day the surface of any solid upon which the sun shines becomes hotter than the air above it. A thermometer resting upon the ground becomes a part of the soil or vegetation, as it were, and the readings of the instrument indicate relatively high or low maximum temperatures in the daytime and relatively high or low minimum temperatures at night, depending upon the radiation, absorption, and conduction of heat under the various existing conditions. The vegetation as found in the bogs is an excellent radiator and absorbs well, but of course conducts and transmits heat to the soil very slowly. The heat lost from vegetation is largely by radiation through the air without heating it sensibly. Peat soil is also a good absorber and radiator, but it is a poor conductor; but the heat received at the surface is partly conducted into the peat. The sanded surface is not as good an absorber, but it is a much better conductor of heat. The heat, moreover, of the sand in the presence of air is lost largely by conduction to it, and consequently serves to heat the air lying immediately above—in strong contrast to the conditions over a heavily vined surface or plain peat, where the loss is mainly by radiation.

A knowledge of these facts is important in connection with the more extensive observations made at Mather during the season of 1907, readings of exposed maximums and of exposed

[a] Bulletin of the Mount Weather Observatory, Vol. II, pt. 3.

minimums being made as well as of soil temperature. The Stations 3, 4, 5, and 6 selected are fairly representative of the conditions prevailing in a cranberry bog. Only the summary of the conditions for 1907, including maximum and minimum averages, appears in Table 3. There is not sufficient space for the daily readings. Four stations, as in the previous year, are sufficient for this comparison, and an additional number would merely repeat the results here furnished. The readings of the maximum and the minimum thermometers are from instruments exposed in the open at the surface. The soil thermometers at the various stations were placed at a depth of 3 inches in the vicinity of the surface thermometers. For purposes of this discussion it would have been better if the bulbs could have been placed just beneath the surface. But in a bog it is rather difficult to determine where the *actual surface* begins, as it is generally covered with vines, grasses, leaves, and decaying vegetation, gradually turning to peat. Where the vegetation is dense, the *effective surface* is actually above the surface of the soil. The sanded surfaces differ radically from the surfaces that are not sanded. On account of these circumstances and because of the difficulty of maintaining the soil thermometers in an upright position, except at a moderate depth, so as to firmly secure them, no attempt was made to obtain readings of the soil temperature at a depth less than 3 inches. In the original tables, of which Table 3 is the summary, the readings of the soil thermometers which were made at 6 p. m. are entered under the succeeding date, and the differences between these readings and the following 7 a. m. readings show the nightly loss or range in soil temperature.

The difficulty in an investigation of this kind is to maintain uniform conditions at the various stations, so that data may be fairly comparable at all times during the season, but this is quite impossible, as the vegetation is likely to remain uniform at one station, while at other stations it may either increase or decrease in density. During the season of 1907 the conditions at Stations 3 and 4 changed but little, the surface at Station 3 being relatively clean, while at Station 4 the vegetation remained dense. The vines at Station 5 were dying out after midsummer to such a degree as to seriously affect the readings of the instruments. In fact, twice during the month of August a change in the location of the soil instruments was made in order to counteract the changing conditions. The density of the vegetation at Station 6 steadily decreased as the end of the season approached, but there was no change in the location of the instruments as at Station 5. If the cranberry vine were a bush, as some people believe, there would not be much difficulty in maintaining uniform conditions of foliage, but it is a vine spreading in all directions from the crown, so that constant trampling at one place often affects the condition of the vegetation several feet distant.

There is, for the reasons given above, a greater uniformity in the readings at Stations 3 and 4 than at the other stations. At Station 3 for the entire season the exposed maximums averaged the lowest and the exposed minimums and the 6 p. m. soil temperatures the highest, although the 7 a. m. soil temperatures averaged the lowest. At Station 5 the exposed maximums averaged the highest from May to August, inclusive, but in September the maximum at Station 4 was slightly higher and in October much higher than at Station 5. The lack in uniformity was undoubtedly caused by the steady change in vegetation at Station 5, as referred to above. This change at Station 5 is also apparent in the comparison of the minimums at Stations 4 and 5, the average minimum in October at Station 4 actually being lower by 0.4° than at Station 5, while in the other months it was considerably higher. The persistency of the dense vegetation at Station 4 until the end of the season is quite apparent from the readings of the instruments, especially in October. It was at Station 4 that the surface minimum averaged lower than at the 5-inch height, as referred to in the discussion of Table 2. On account of the enforced change of the soil instruments at Station 5 in August, these readings are not strictly comparable in September and October with the soil data at the other stations.

At Stations 4, 5, and 6 the soil was so shielded from the sun's rays as to prevent its warming to any great degree, much of the absorbed energy being used to produce plant growth and evaporation, and consequently the loss or range of heat was small as compared with that at Station 3. The difference in range of soil temperature at the 3-inch depth at certain stations,

caused by variation in soil and covering, at Mather, Wis., is graphically shown in Figure 19; also in Figure 20, which shows the average hourly soil temperature at depths of 3 and 6 inches at Stations 3 and 5.

While the 7 a. m. or minimum soil temperature readings at the *depth of 3 inches* at Station 3 averaged lower than at the other stations, it is probable that the minimum temperature of the soil at the *immediate surface* at Station 3 averaged higher than at the other locations, because the exposed minimum temperature was higher. As the exposed maximum temperature at the various stations was affected by the vegetation, so also was the exposed minimum,

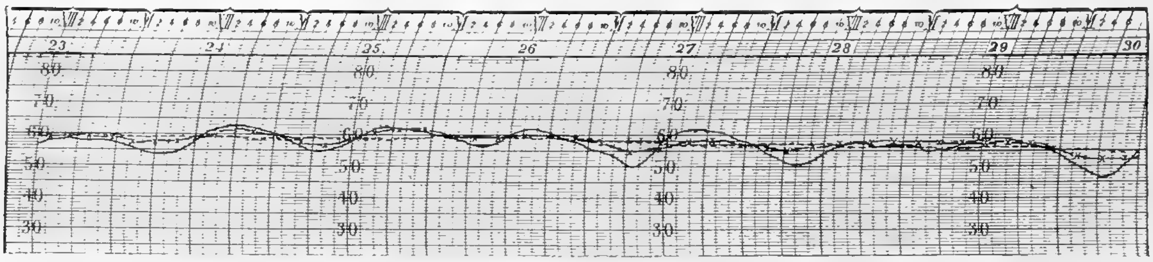

Fig. 19.—Soil temperature curves at three inch depth for Stations 3, 4, and 5, Mather, Wis., September 23 to 30, 1906. Station No. 3, soil temperature in bog newly sanded, thinly vined, 3 inches deep ______; station No. 5, soil temperature in peat bog with moss 3 inches deep ; station No. 4, soil temperature in bog newly sanded, heavily vined, 3 inches deep —x—x—x—x—x—.

the lowest minimums prevailing generally at the stations where the maximums were the highest. Obviously the increasing vegetation, serving to raise the exposed maximum in the daytime, was also responsible for the great radiation at night, especially during clear weather, and as a consequence the minimums were lowest where the vegetation was densest and highest where it was thinnest. While the loss of heat at night from the vegetation is largely by radiation and through the air without warming it, at places where the surface was sanded the loss of heat was partly by conduction to the air above. Although the vegetation was dense at Station 4, the surface had been recently sanded, and the surface at Station 6 had been sanded in 1898. The influence of this sanding at Station 4 and even at Station 6 is apparent in the readings of the maximum soil temperature, the range in soil temperature, and the exposed minimum temperature, as compared with similar readings at Station 5, although a layer of peat an inch in thickness had formed over the sand at Station 6. The vegetation at all three stations was dense and prevented great heating of the soil, but nevertheless the sand, being a better conductor of heat than the peat, brought a greater supply of heat into the soil, thus conserving it to be given off later at night by conduction and radiation. The sand, then, was probably as much responsible as the better drainage for the higher exposed minimum temperatures at Stations 4 and 6, as compared with Station 5, the drainage at both Stations 5 and 6 being relatively poor, resulting in a considerable loss of heat through evaporation of the moisture at the surface. The conditions at Station 6 resembled those at Stations 4 and 5 equally, because although the vegetation at Station 6 was dense until after midsummer, it gradually died away, and for this reason the exposed maximums averaged during October even lower than those at Station 3.

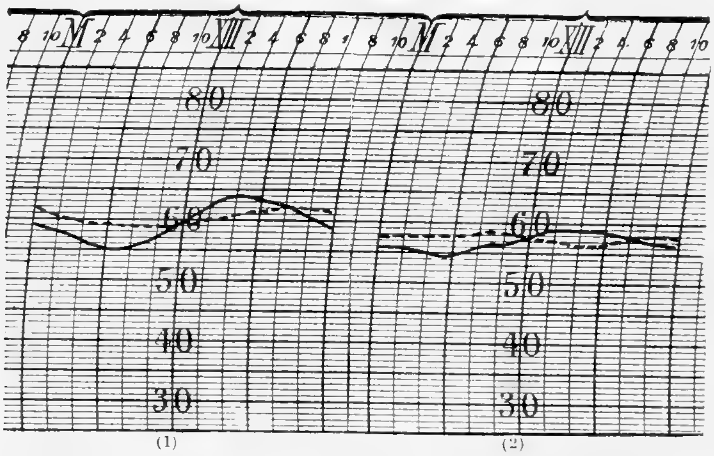

Fig. 20.—(1) Traces showing average hourly soil temperature for the season of 1907 at a depth of 3 inches and 6 inches, Station 3, Mather, Wis. (3 inches ______, 6 inches .) (2) Traces showing average hourly soil temperatures for the season of 1907 at depths of 3 inches and 6 inches, Station 5, Mather, Wis. (3 inches ______, 6 inches ------------.)

These observations in 1907 confirm those of 1906 in that the highest maximum soil temperatures and the lowest minimum soil temperatures at the depth of 3 inches, the greatest range in soil temperature, and the highest exposed minimums occurred in the thinly vined, well drained, and sanded sections, while the lowest maximum soil temperatures and highest minimum soil temperatures, the least range in soil temperature, and the lowest exposed minimums were found in the uncultivated marsh, which was poorly drained and heavily vined. Moreover, the highest average exposed maximums occurred where the vegetation was dense, while the lowest average maximums occurred in the sanded and thinly vined section. Other things being equal, the higher the maximum temperature on any one day the higher was the maximum soil temperature at the depth of 3 inches and the ensuing exposed minimum temperature. Again, other things being equal, the higher the maximum soil temperature on any one day the higher was the ensuing exposed minimum temperature. In other words, there was a close relation between the daily maximum air temperature and the soil temperature and a close relation between the soil temperature and the ensuing exposed minimum temperature. It is for this reason that in the spring and fall, when the ground is cold, frost occurs in the bogs much more easily than in the summer, when the soil is warm.

The high exposed minimums at Station 3, as compared with those at the other stations, are quite remarkable, and the advantages from cultivation, draining, and sanding are well illustrated. The difference between the minimum temperatures at Station 3 and at the other stations is least in October, and this is probably because frost had entered the *surface* of the soil. Whereas sand during the crop season is most valuable in warding off low night temperatures, it is probable that after frost has once entered the soil its character is not of much consequence. While the exposed maximums on cloudy days varied little at the different stations and did not reach a high degree, the minimum temperatures on cloudy nights differed little and were relatively high. There was, moreover, but little difference between the minimums on windy nights. At no station during the season did the temperature of the soil at the depth of 3 inches fall to the freezing point, the lowest reading being 33.8° on the morning of October 28 at Station 3. On the same day the readings at the other stations were as follows: Station 4, 37.1°; Station 5, 40.3°; and at Station 6, 37°; but at all stations on the bog the ground at the immediate surface was frozen.

The range in the exposed minimum temperature at the surface of a bog, as shown by Tables 2 and 3, does not, of course, actually represent the extremes, the exposed minimums at the 5-inch height as a rule registering lower than those at the surface. In later tables embodying the daily readings of the exposed minimums, both at the surface and 5 inches and their respective differences, will be shown in detail the extreme differences at the coldest and the warmest places on the bogs.

The highest exposed maximums were reached about July 20, the greatest being 128.1° on that date at Station 5. On the same date the exposed maximum at Station 3 was 110°; at Station 4, 121.7°; and at Station 6, 120°. The soil temperature readings at 6 p. m. at Stations 4, 5, and 6, reached their maximum from four to five days later, there being an irregular increase from the beginning of the season in May to the summer maximum, and, in turn, a decrease from the maximum to the minimum near the end of October. The highest soil temperatures at the various stations in July were as follows: Station 3, 76.3° on the 20th; Station 4, 69.7° on the 24th; Station 5, 71° on the 25th; and Station 6, 71.5° on the 24th. The maximum of the season, however, at Station 3, in the thinly vined and sanded section, was not reached until August 31, when a temperature of 78° was registered. The exposed maximums at Station 3 seldom registered higher than 110°, but at Stations 4, 5, and 6, where the vegetation was dense, the readings frequently exceeded 120°. The greatest daily range between the exposed maximum and the exposed minimum at any one station was at Station 5, 89.9°, on July 2, from a maximum of 119.9° to a minimum of 30°. The daily range in exposed temperature was seldom less than 20°, except at Station 3. At that station there were a few instances of ranges less than 10° in October, and one or two others during the balance of the season.

There is, of course, a direct relation between the air temperature and the soil temperature, an increase of heat during the day serving to raise the temperature of the soil; and this, in turn, prevents low minimum temperatures at night. Where the air temperature was low in the daytime, and, as a result, the soil remained cold, low minimum air temperatures were sure to follow, provided the weather at night was clear, so as to permit free radiation of heat. While usually there was a loss of heat from the soil at night, occasionally the temperature of the soil rose. On October 2, during a cloudy, warm night, following a cold day, the temperature of the soil rose at the various stations, the increase reaching a maximum of 1.7° at Station 6. On certain cloudy, warm nights there was a slight rise in the soil temperature at Stations 4, 5, and 6, while a fall occurred at Station 3. The greatest nightly loss in soil temperature was at Station 3, 17.8° on October 18, from a maximum of 57° to a minimum of 39.2°, while at the other stations the nightly loss in soil temperature seldom exceeded 5°. The range in soil temperature is a measure of the heat absorbed during the day and lost at night by the soil, and responds from day to day to changes in insolation.

The amount of heat received in the daytime by the soil at the different locations is shown in a measure by the 6 p. m. soil-temperature readings. At the 3-inch depth the average for the season of 1907 at Station 3 was 62.6°, as compared with 58° at Station 4, 56.6° at Station 5, and 57.2° at Station 6. (Tables 3 and 19.) Moreover, at the 6-inch depth, the average soil-temperature readings were as follows: Station 3, 59.8°; Station 4, 56.2°; Station 5, 55.2°; Station 6, 55.6°. These figures not only show that the temperature of the soil near the surface in the thinly vined and sanded section is usually much higher than in the other sections, but also that the heat reaches to a greater depth. In this connection, see Figure 20, showing the soil-temperature curves at both 3 and 6 inches at Stations 3 and 5 for the season of 1907. The range in temperature of the soil immediately beneath the surface is undoubtedly greater than at the depth of 3 inches. It should be evident that where the soil temperatures are high, more heat may be lost by conduction and radiation from the soil before the point of critical air temperature at or immediately above the surface is reached, even if the loss by radiation through the air be at the same rate at all locations. However, the radiation from a peat bog with a heavily vined surface is much freer than where the surface has been sanded and is thinly vined, the loss of heat from the latter probably being largely by conduction to the air, and therefore slower. The sanded and thinly vined surface conserves the heat, not only in the soil, but also in the air immediately above, while a dense growth of vegetation prevents the soil beneath from being heated considerably in the daytime. The degree to which the temperature falls during the night depends largely upon the warmth of the soil, and when the heating during the day has been slight, and the ensuing night is clear, thus permitting rapid radiation, low minimum air temperatures must result, as stated above.

It is apparent from this discussion that the air temperature is controlled largely by the character of the soil and its covering. Such a remarkable variation as is here shown explains why frost may visit one portion of a bog, while another portion may escape injury. On any clear, cool night the cold air, as it settles gradually through gravity, overspreads the bog, and here and there are found warm places and cold places and others having an intermediate value, depending upon the character of the soil and its covering. It is as if heaters of varying power were scattered over the bog, giving off heat to the air immediately above, some in greater quantities and others in less. The difference in temperature of a surface covering is sometimes apparent when the first light snow falls in the autumn or early winter, before the ground becomes cold, the snow melting where the ground is bare of growth, but remaining where the vegetation is dense. Likewise, under similar conditions, snow melts when it falls upon a concrete walk, though remaining on a board walk; and the first frost of the season is always seen on the latter. The heat stored in the bare soil and in the concrete walk is conducted to the surface, and affects the temperature at the surface as does a sanded and thinly vined soil in the bogs. Figures 21 and 22 will supplement Table 3.

Table 3.—Monthly and Seasonal Means of Maximum and Minimum Temperatures at Surface in Open, with Range; also Means of Soil Temperatures, 3-inch Depth, and of Loss during the Night, Mather, Wis., 1907.

[The 6 p. m. soil temperatures occurred the previous day.]

	May.[a]	June.	July.	Aug.	Sept.	Oct.	Means.
Station 3:							
Surface—	°	°	°	°	°	°	°
Maximum	79.5	95.7	99.6	89.9	80.9	62.1	84.6
Minimum	40.2	48.8	55.5	53.7	45.9	28.8	45.5
Range	39.3	46.9	44.1	36.2	35.0	33.3	39.1
Soil, 3 inch							
6 p. m.	56.3	65.9	71.8	68.6	63.2	49.6	62.6
7 a. m.	48.0	56.9	63.1	61.4	55.3	41.9	54.4
Loss	−8.3	−9.0	−8.7	−7.2	−7.9	−7.7	−8.2
Station 4:							
Surface—							
Maximum	84.5	103.4	110.1	99.4	85.4	72.7	92.6
Minimum	38.2	45.2	52.3	50.6	44.2	27.5	43.0
Range	46.3	58.2	57.8	48.8	41.2	45.2	49.6
Soil, 3 inch—							
6 p. m.	50.5	60.2	66.9	64.6	59.3	46.6	58.0
7 a. m.	47.6	56.5	63.2	61.5	56.5	44.0	54.9
Loss	−2.9	−3.7	−3.7	−3.1	−2.8	−2.6	−3.1
Station 5:							
Surface—							
Maximum	84.7	104.4	112.2	101.3	85.0	64.7	92.0
Minimum	36.8	43.5	49.8	48.8	43.0	27.9	41.7
Range	47.9	60.9	62.4	52.5	42.0	36.8	50.3
Soil, 3 inch—							
6 p. m.	48.6	57.9	66.2	64.0	57.2	45.9	56.6
7 a. m.	47.6	55.6	63.6	62.1	56.5	45.5	55.1
Loss	−1.0	−2.3	−2.6	−1.9	−0.7	−0.4	−1.5
Station 6:							
Surface—							
Maximum	80.1	99.8	105.9	97.1	81.4	60.1	87.4
Minimum	38.6	44.0	50.3	49.3	43.1	28.3	42.3
Range	41.5	55.8	55.6	47.8	38.3	31.8	45.1
Soil, 3 inch—							
6 p. m.	49.5	59.1	65.9	63.6	58.5	46.6	57.2
7 a. m.	47.3	56.3	63.4	61.4	56.3	44.6	54.9
Loss	−2.2	−2.8	−2.5	−2.2	−2.2	−2.0	−2.3

[a] Means for sixteen days.

Station 3. Newly sanded, thinly vined.
Station 4. Newly sanded, heavily vined.
Station 5. Peat with moss, heavily vined.
Station 6. Old sanded, heavily vined.

Air temperatures and soil temperatures at Station 7 and Station 7a, Mather, Wis., September, 1906.—The facts brought out by the comparative data appearing in Table 3 are accentuated by observations made in 1906 at Station 7, and at a supplementary station, 7*a*, which show how much the minimum temperature at an elevation above the surface depends upon the environment. When the investigation was commenced in 1906 at Mather it seemed desirable to have one station located in a section of plain peat, absolutely free from vegetation. No such section was available, nor was it practicable to scalp a portion of the cranberry marsh proper for the purpose. An area, however, 10 feet square, in the midst of an extensive field of sphagnum moss, immediately outside, was cleaned up. Thermometers were placed in the

center of the scalped piece, Station 7, and 5 or 6 feet distant over the moss, Station 7*a*, near the edge. Station 7*a* was not continued in 1907, and as Station 7 itself was under water for a considerable portion of the same year, data for 1907 at that Station are not as serviceable as they otherwise might be. Data for September, 1906 (Table 4), furnish some interesting results. The average exposed minimum at the surface of Station 7 was much higher than at the surface at Station 7*a*, there being a difference of 5.6°. On every day the minimum was higher at the surface of Station 7 than at the surface at Station 7*a*, with but a single exception, and a maximum difference of 11° occurred on September 25—a remarkable variation in temperature within a distance of 5 or 6 feet. This is because, in a soil covered with a thick layer of moss, the opportunity for conduction down is not good, and much of the absorbed solar energy is used in producing plant growth. Thus the moss-covered soil does not store up as much sensible heat as does the bare soil, although the moss and the bare peat are equally good radiators.

The difference between the average minimums for the month at an elevation of 5 inches, however, was only 0.5°, Station 7 still reading higher on the average, although there were several instances where it was lower. *The minimum at the 5-inch height at Station 7 averaged 4.8° lower than at the surface, while at Station 7a the temperature at 5 inches averaged 0.3° higher than at the surface.* This inversion of the usual conditions at Station 7*a* was doubtless caused by the warmth from the area of bare soil adjoining. In other words, the temperature at the 5-inch height over the bare peat at Station 7 was affected by the surrounding area of sphagnum moss, and consequently lowered, while the temperature over the adjoining moss at Station 7*a* was affected in the other direction, but in a lesser degree, by the small area of bare peat immediately adjoining. There was probably a slow circulation of air at night between the moss and the bare soil. These results indicate quite plainly that while the temperature at the surface depends upon the character of the soil and vegetation at the point of exposure, the temperature a few inches above is affected not only by the character of this vegetation and the soil immediately beneath, but by the environment as well. If the scalped piece were greater in extent, 40 or 50 feet square or more, the thermometers exposed in the center of the area 5 inches above the ground would probably not be considerably affected by the surrounding moss. The thermometer on the moss, however, near the edge of this larger scalped piece, would, on the other hand, be affected even more than in the case of the small 10-foot area used in this investigation.

Table 4, under the soil-temperature column, at the 3-inch depth, illustrates the great range in temperature of the clean soil as compared with that covered with a dense growth. The average 6 p. m. reading at Station 7 was 65.8°, as compared with 61.3° at Station 7*a*. The maximum soil temperature was 73° at Station 7 on September 12, while it was only 63.8° at Station 7*a* on the same day. The average loss of heat during the night at Station 7 was 6.1°, as compared with 0.2° at Station 7*a*, while the minimum, or 7 a. m. soil readings, averaged lower at Station 7 than at Station 7*a*, at the 3-inch depth. The greatest loss in soil temperature at both stations was on September 14, 11.2° at Station 7, and only 1.2° at Station 7*a*. On September 16, during a warm, rainy night, following a cool day, the soil temperature at Station 7 actually rose 0.5°, while at Station 7*a* the rise was 0.6°. On the night of September 2 the soil temperature at Station 7 rose 0.2°, while at Station 7*a* the rise was 0.4°. These were the only instances where the temperature rose in the nighttime at Station 7, but there were a number of instances where the temperature rose at Station 7*a*, its soil being so protected from the sun's rays that the change in temperature was not only small, but lagged behind that at Station 7. The moss loses its heat rapidly and receives heat from below but slowly, partly because the supply there is not great and partly because the connection, being mainly through the stems, is not such as to give good conduction. On the other hand, the bare peat soil has a good supply of heat to draw upon and has direct connection with the atmosphere above.

While the minimum temperature at the depth of 3 inches was lower in the bare section than in the moss, it is quite certain that at the immediate surface the temperature in the bare soil was higher. It is apparent that the bare soil conserves the heat, while a soil covered with a dense growth, such as moss, is heated but little by the sun's rays, an exposed minimum there-

fore at the immediate surface of the clean section registering much higher than over the moss. The varying temperature of the ground is further evidenced by the habits of cattle in pasture. On warm summer nights they lie down where the ground is covered with grass, so as to be cool, while on cool, clear nights they seek the warmer bare soil.

Table 4.—Minimum Temperatures in Open at Surface and 5-Inch Height, Together with Differences; also Soil Temperature Readings Showing Loss during Night, Mather, Wis., September, 1906.

[The 6 p. m. soil readings are those which occurred the previous day.]

Day of month.	Station 7 (over bare peat).						Station 7a (over sphagnum moss).					
	Surface.	5 inches.	Difference.	Soil temperature, 3 inches deep.			Surface.	5 inches.	Difference.	Soil temperature, 3 inches deep.		
				6 p. m.	7 a. m.	Loss.				6 p. m.	7 a. m.	Loss.
	°	°	°	°	°	°	°	°	°	°	°	
1	43.5	38.8	−4.7	65.3	57.8	− 7.5	37.8	36.0	−1.8	61.0	60.7	−0.3
2	61.5	60.7	−0.8	62.1	62.3	+ 0.2	61.0	61.2	+0.2	60.8	61.2	+0.4
3	42.5	35.0	−7.5	65.2	58.5	− 6.7	32.2	31.0	−1.2	61.8	61.5	−0.3
4	41.4	35.0	−6.4	67.0	57.3	− 9.7	34.4	34.0	−0.4	61.3	60.8	−0.5
5	40.0	32.4	−7.6	67.0	57.3	− 9.7	31.1	30.6	−0.5	60.8	60.4	−0.4
6	42.4	35.7	−6.7	66.5	57.2	− 9.3	36.0	35.5	−0.5	60.3	60.0	−0.3
7	49.0	43.4	−5.6	67.8	60.3	− 7.5	43.2	43.7	+0.5	60.3	60.4	+0.1
8	52.2	46.8	−5.4	69.8	61.8	− 8.0	46.4	47.0	+0.6	60.8	61.0	+0.2
9	53.1	47.2	−5.9	71.3	62.9	− 8.4	47.3	47.0	−0.3	61.4	61.6	+0.2
10	60.8	56.0	−4.8	72.8	66.3	− 6.5	55.2	57.8	+2.6	62.1	62.5	+0.4
11	61.5	*61.8*	*+0.3*	71.0	*67.2*	− 3.8	*62.0*	57.9	*−4.1*	62.8	63.3	+0.5
12	62.2	59.5	−2.7	*73.0*	*67.2*	− 5.8	60.1	60.4	+0.3	*63.8*	*63.9*	+0.1
13	50.3	47.2	−3.1	69.2	62.5	− 6.7	47.3	48.3	+1.0	*63.8*	63.4	−0.4
14	36.2	29.3	−6.9	67.0	55.8	*−11.2*	29.0	28.1	−0.9	62.8	61.6	*−1.2*
15	47.0	45.0	−2.0	62.2	51.8	−10.4	44.3	46.0	+1.7	61.0	60.3	−0.7
16	*62.5*	61.0	−1.5	61.6	62.1	*+ 0.5*	*62.0*	*62.3*	+0.3	60.3	60.9	*+0.6*
17	60.7	57.4	−3.3	68.3	64.3	− 4.0	57.1	58.0	+0.9	61.9	62.4	+0.5
18	62.4	58.3	−4.1	70.3	65.8	− 4.5	57.8	58.2	+0.4	63.0	63.3	+0.3
19	55.4	51.1	−4.3	71.2	64.7	− 6.5	49.2	51.2	+2.0	63.7	63.7	0.0
20	56.0	53.3	−2.7	69.4	63.5	− 5.9	54.0	54.1	+0.1	63.5	63.2	−0.3
21	54.1	49.5	−4.6	65.4	62.4	− 3.0	48.8	50.2	+1.4	63.0	62.8	−0.2
22	50.7	44.3	−6.4	67.0	60.8	− 6.2	42.8	43.2	+0.4	62.8	62.2	−0.6
23	46.7	40.2	−6.5	60.5	57.8	− 2.7	40.0	41.1	+1.1	61.8	61.1	−0.7
24	44.0	37.5	−6.5	59.7	56.2	− 3.5	35.8	36.0	+0.2	60.7	60.0	−0.7
25	45.0	36.8	*−8.2*	62.5	56.4	− 6.1	34.0	35.2	+1.2	60.1	60.0	−0.1
26	45.8	41.5	−4.3	63.3	59.5	− 3.8	38.0	40.3	+2.3	59.8	60.2	+0.4
27	33.2	27.0	−6.2	61.3	52.0	− 9.3	26.9	25.3	−1.6	59.7	58.7	−1.0
28	36.7	30.4	−6.3	61.0	52.7	− 8.3	28.4	29.0	+0.6	58.2	57.7	−0.5
29	43.0	42.0	−1.0	*57.8*	56.5	− 1.3	35.0	42.2	*+7.2*	*57.5*	57.8	+0.3
30	*29.3*	*22.5*	−6.8	59.0	*49.8*	− 9.2	*24.3*	*20.3*	−4.0	57.8	*57.0*	−0.8
Means	49.0	44.2	−4.8	65.8	59.7	− 6.1	43.4	43.7	+0.3	61.3	61.1	−0.2

Highest and lowest readings are in italics.

TABLE 4.—COMPARISON OF MINIMUM TEMPERATURES AT STATIONS 7 AND 7*a*, MATHER, WIS., SEPTEMBER, 1906.

Day of month.	Surface.			5-inch height.		
	Station 7.	Station 7*a*.	Difference.	Station 7.	Station 7*a*.	Difference.
	°	°	°	°	°	°
1	43.5	37.8	− 5.7	38.8	36.0	−2.8
2	61.5	61.0	− 0.5	60.7	61.2	+0.5
3	42.5	32.2	−10.3	35.0	31.0	*−4.0*
4	41.4	34.4	− 7.0	35.0	34.0	−1.0
5	40.0	31.1	− 8.9	32.4	30.6	−1.8
6	42.4	36.0	− 6.4	35.7	35.5	−0.2
7	49.0	43.2	− 5.8	43.4	43.7	+0.3
8	52.2	46.4	− 5.8	46.8	47.0	+0.2
9	53.1	47.3	− 5.8	47.2	47.0	−0.2
10	60.8	55.2	− 5.6	56.0	57.8	*+1.8*
11	61.5	*62.0*	*+ 0.5*	*61.8*	57.9	−3.9
12	62.2	60.1	− 2.1	59.5	60.4	+0.9
13	50.3	47.3	− 3.0	47.2	48.3	+1.1
14	36.2	29.0	− 7.2	29.3	28.1	−1.2
15	47.0	44.3	− 2.7	45.0	46.0	+1.0
16	*62.5*	*62.0*	− 0.5	61.0	*62.3*	+1.3
17	60.7	57.1	− 3.6	57.4	58.0	+0.6
18	62.4	57.8	− 4.6	58.3	58.2	−0.1
19	55.4	49.2	− 6.2	51.1	51.2	+0.1
20	56.0	54.0	− 2.0	53.3	54.1	+0.8
21	54.1	48.8	− 5.3	49.5	50.2	+0.7
22	50.7	42.8	− 7.9	44.3	43.2	−1.1
23	46.7	40.0	− 6.7	40.2	41.1	+0.9
24	44.0	35.8	− 8.2	37.5	36.0	−1.5
25	45.0	34.0	*−11.0*	36.8	35.2	−1.6
26	45.8	38.0	− 7.8	41.5	40.3	−1.2
27	33.2	26.9	− 6.3	27.0	25.3	−1.7
28	36.7	28.4	− 8.3	30.4	29.0	−1.4
29	43.0	35.0	− 8.0	42.0	42.2	+0.2
30	*29.3*	*24.3*	− 5.0	*22.5*	*20.3*	−2.2
Means	49.0	43.4	− 5.6	44.2	43.7	−0.5

Highest and lowest readings are in italics.

Minimum temperatures at the coldest and the warmest points on the bog, Mather, Wis.—From the foregoing it is obvious that great extremes of temperature occur in any bog, and that there is a wide range in minimum temperature in various portions of the same bog. It has, moreover, been found from the discussion of previous tables that at four selected stations the exposed minimum surface readings were highest at Station 3 and lowest at Station 5, and that at both Stations 3 and 5 the exposed minimum at the 5-inch height registered lower than the one at the surface. Stations 2 and 5 were equally cold, Station 5 being in the cranberry bog, in an uncultivated section, while Station 2 was immediately outside, in a field of sphagnum moss. The observations at Station 5, although sometimes interrupted by reflowing, are preferable in this comparison with Station 3, because of the location of the station among the vines. Stations 3 and 5, then, may be considered as being the warmest and the coldest places on the bog, and the exposed minimums at these two stations will be discussed in detail; first, between the readings of the surface thermometers at both stations during the season of 1907; second, between the surface minimum at Station 3 and the minimum at the 5-inch height at Station 5; and, third, between the last-named readings and the readings of the minimum in the shelter at Station 1, which, of course, should be the standard for comparison with other stations. (See Tables 5, 5*a*, 6, 6*a*, 7, 7*a*.)

The exposed minimums at the surface at Station 3, the thinly vined, sanded, and well drained section, were usually higher than those at Station 5, over peat and moss, heavily vined and with poor drainage. (Table 5.) The difference between the readings gradually but irregularly increased from spring to midsummer, after which it decreased until the end of the season. The average difference by months was as follows: May, 3.3°; June, 5.3°; July, 5.7°;

August, 4.9°; September, 2.9°; October, 0.8°; while the greatest daily difference in each month was 8.9°, May; 8.8°, June; 9.6°, July; 10.2°, August; 7.1°, September; and 4.3°, October. The daily readings at Station 3 were almost invariably much higher than at Station 5, with the exception of the month of October; and but three times during May, June, and July did the instruments at Station 5 register higher than at Station 3. These differences were 0.3° on May 15, 1° on June 26, and 1.6° on July 22. In August and September there were no instances in which the thermometers at Station 5 registered higher than at Station 3, while in October there were ten days. The changed relation between the readings in October is undoubtedly due to the fact that frost had entered the sanded soil at Station 3, as well as the peat soil at Station 5; and it is probable, as has been said before, that when once frost enters the soil, its character, whether it be peat or sand, is of little consequence in affecting night temperatures. Moreover, the vegetation at Station 5 was gradually dying out toward the end of the season, while at Station 3 the conditions changed but little. It is interesting to note that on the coldest day of the entire season, October 28, the temperature at Station 3 was 13.9°, 0.3° lower than at Station 5, 14.2°. In the other months, however, the minimums at the sanded section were several degrees higher than in the uncultivated bog. At Station 5 there were several instances of freezing temperature during the first decade of June, and one on July 2; on that date the exposed minimum at the surface of Station 5 registering 30°, while at the surface at Station 3 the reading was 38.8°. Whenever the readings of the instruments were seriously affected by reflowing to ward off frost, a proper explanation has been made in the tables, and the values of the readings estimated. It is unfortunate that on September 22, 25, and 26 actual readings of the instruments at Station 3 were not available, as the portion of the bog in which that station was located was covered with water. In Table 5*a* will be found the monthly and the seasonal averages for the exposed minimums at the surface of Stations 3 and 5.

A still further comparison is made in Tables 6 and 6*a*, showing the difference in readings between the surface thermometer at Station 3 and the thermometer at 5 inches at Station 5. These may be accepted as being approximately the extremes of minimum temperature to which the vegetation in the bog is subjected. The surface minimum at Station 3 averaged higher than any other minimum exposed in the open, while the thermometer at 5 inches at Station 5 averaged the lowest. The average and extreme differences between these instruments were, of course, even greater than those noted in the discussion of Table 5. The average seasonal difference was 4.4°, and the greatest average monthly difference was 7° in June, while the least monthly differences were 3.2° and 3.8° in May and October, respectively. The greatest daily difference in May was 7°; in June, 11.9°; July, 11°; August, 12.8°; September, 10.6°; and in October, 9°. There were but five instances throughout the entire season when the daily minimum at the surface of Station 3 was lower than the upper thermometer at Station 5. The lowest reading in May at the surface at Station 3 was 21.1°, while at 5 inches at Station 5 on the same day the reading was 17°; in the other months the lowest readings were respectively as follows: June, 33.8° (estimated), and 26.2°; July, 38.8° and 27.9°; August, 42.5° and 33°; September, 24.5° and 16.6°; and in October, 13.9° and 6.4°.

TABLE 5.—COMPARISON OF MINIMUM TEMPERATURES IN OPEN AT THE SURFACES OF STATIONS 3 AND 5, WITH DIFFERENCES. MATHER, WIS., 1907.

Day of month.	May.[a]			June.			July.		
	Station 3.	Station 5.	Difference.	Station 3.	Station 5.	Difference.	Station 3.	Station 5.	Difference.
	°	°	°	°	°	°	°	°	°
1				34.0	30.9	−3.1	59.5	56.0	−3.5
2				38.3	29.6	−8.7	*38.8*	*30.0*	−8.8
3				52.9	48.0	−4.9	47.2	40.9	−6.3
4				43.0	35.5	−7.5	51.5	46.3	−5.2
5				44.1	42.0	−2.1	58.2	58.0	−0.2
6				[c] *33.8*	28.6	−5.1	57.9	53.0	−4.9
7				49.5	45.2	−4.3	50.5	45.0	−5.5
8				36.1	*28.1*	−8.0	54.4	48.2	−6.2
9				42.4	34.8	−7.6	58.8	51.5	−7.3
10				53.7	52.7	−1.0	50.0	43.0	−7.0
11				44.0	42.7	−1.3	62.0	61.3	−0.7
12	37.3	33.9	−3.4	53.1	51.0	−2.1	49.6	43.2	−6.4
13	*56.5*	*52.8*	−3.7	42.6	33.8	*−8.8*	52.9	46.8	−6.2
14	46.8	45.2	−1.6	39.3	31.0	−8.3	61.0	57.0	−4.0
15	39.0	39.3	*+0.3*	42.9	41.0	−1.9	*68.9*	*66.2*	−2.7
16	36.9	36.1	−0.8	53.5	45.9	−7.6	54.0	47.1	−6.9
17	39.0	32.4	−6.6	*66.6*	*60.2*	−6.4	53.3	46.7	−6.6
18	41.9	34.0	−7.9	57.7	50.4	−7.3	51.2	43.7	−7.5
19	35.0	33.1	−1.9	56.3	47.8	−8.5	56.9	51.3	−5.6
20	23.7	*16.8*	−6.9	51.0	44.0	−7.0	58.1	71.0	−7.1
21	*21.1*	18.3	−2.8	49.3	43.8	−5.5	65.9	60.2	−5.7
22	44.9	40.8	−4.1	62.3	59.4	−2.9	[c] 63.8	[d] 65.4	*+1.6*
23	45.0	43.8	−1.2	60.3	56.5	−3.8	55.0	[c] 47.0	−8.0
24	42.1	33.2	*−8.9*	54.9	50.4	−4.5	62.2	[c] 58.2	−4.0
25	45.0	45.0	0.0	58.9	56.1	−2.8	54.9	[c] 46.8	−8.1
26	46.0	45.4	−0.6	49.0	50.0	*+1.0*	52.8	[c] 43.2	*−9.6*
27	([b])	([b])		44.0	36.8	−7.2	47.5	[c] 39.2	−8.3
28	([b])	([b])		45.0	37.1	−7.9	58.1	54.0	−4.1
29	35.9	33.0	−2.9	50.0	42.3	−7.7	58.0	51.0	−7.0
30	43.0	38.4	−4.6	55.4	49.0	−6.4	50.3	43.0	−7.3
31	48.3	46.7	−1.6				57.4	50.4	−7.0
Means	40.4	37.1	−3.3	48.8	43.5	−5.3	55.5	49.8	−5.7

[a] Means for eighteen days.
[b] Readings not obtained; marsh flooded.
[c] Estimated; actual readings valueless on account of reflowing.
[d] Affected by water.

Station 3. Newly sanded, thinly vined. Station 5. Peat with moss, heavily vined.

Highest and lowest readings are in italics.

TABLE 5.—COMPARISON OF MINIMUM TEMPERATURES IN OPEN AT SURFACES OF STATIONS 3 AND 5, WITH DIFFERENCES, MATHER, WIS., 1907—Continued.

Day of month.	August.			September.			October.		
	Station 3.	Station 5.	Difference.	Station 3.	Station 5.	Difference.	Station 3.	Station 5.	Difference.
	°	°	°	°	°	°	°	°	°
1	55.1	50.9	− 4.2	64.1	61.4	−2.7	30.8	28.5	−2.3
2	49.0	42.2	− 6.8	53.9	46.8	*−7.1*	*46.1*	*47.1*	+1.0
3	47.1	43.0	− 4.1	48.8	43.3	−5.5	41.6	38.3	−3.3
4	43.1	*35.0*	− 8.1	52.7	48.8	−3.9	33.6	32.0	−3.5
5	61.3	58.6	− 2.7	46.7	42.0	−4.7	36.3	32.0	*−4.3*
6	53.0	46.2	− 6.8	41.2	36.0	−5.2	38.7	37.0	−1.7
7	59.0	55.0	− 4.0	56.5	55.6	−0.9	42.1	39.7	−2.4
8	56.6	52.0	− 4.6	57.2	56.2	−1.0	21.8	19.5	−2.3
9	54.0	49.6	− 4.4	39.0	36.6	−2.4	34.6	35.0	+0.4
10	59.8	54.0	− 5.8	a 37.0	a 34.1	−2.9	28.5	28.5	0.0
11	*68.7*	*66.0*	− 2.7	43.7	39.2	−4.5	30.1	30.3	+0.2
12	49.7	43.0	− 6.7	43.3	40.0	−3.3	28.4	28.7	+0.3
13	48.9	43.0	− 5.9	45.7	42.8	−2.9	19.0	18.8	−0.2
14	52.3	46.3	− 6.0	56.5	55.0	−1.5	17.7	18.4	+0.7
15	56.6	50.6	− 6.0	57.7	54.3	−3.4	40.7	41.8	+1.1
16	62.1	59.0	− 3.1	*65.1*	*64.5*	−0.6	33.1	31.8	−1.3
17	51.2	44.5	− 6.7	51.0	46.5	−4.5	30.8	30.5	−0.3
18	54.8	50.0	− 4.8	59.0	58.6	*−0.4*	23.6	25.4	+1.8
19	65.5	65.0	− 0.5	60.4	59.5	−0.9	19.7	18.8	−0.9
20	46.6	37.9	− 8.7	59.4	58.0	−1.4	26.3	27.0	+1.3
21	48.4	38.2	*−10.2*	37.4	35.2	−2.2	17.5	14.6	−3.1
22	*42.5*	38.0	− 4.5	a 30.3	24.7	−5.6	28.5	27.3	−1.2
23	54.0	48.1	− 5.9	41.7	41.3	*−0.4*	24.5	21.8	−2.7
24	50.7	46.1	− 4.6	44.0	43.3	−0.7	21.3	20.5	−0.8
25	42.7	36.8	− 5.9	a 27.2	24.8	−2.4	23.6	23.5	−0.1
26	49.8	43.8	− 6.0	a 33.0	26.7	−6.3	16.8	14.7	−2.1
27	57.2	57.0	*− 0.2*	32.7	28.8	−3.9	32.3	32.0	−0.3
28	54.0	52.1	− 1.9	38.4	38.0	*−0.4*	*13.9*	*14.2*	+0.3
29	50.7	46.0	− 4.7	30.0	26.5	−3.5	24.6	24.4	−0.2
30	62.9	62.1	− 0.8	*24.5*	*21.3*	−3.2	36.2	35.9	−0.3
31	56.3	54.2	− 2.1	....	....	....	30.0	30.6	+0.6
Means	53.7	48.8	− 4.9	45.9	43.0	−2.9	28.8	28.0	−0.8

TABLE 5a.—MONTHLY AND SEASONAL MEANS, STATIONS 3 AND 5, MATHER, WIS., 1907.

	May.[b]	June.	July.	August.	September.	October.	Seasonal means.
Surface:	°	°	°	°	°	°	°
Station 3	40.4	48.8	55.5	53.7	45.9	28.8	45.5
Station 5	37.1	43.5	49.8	48.8	43.0	28.0	41.7
Difference	− 3.3	− 5.3	− 5.7	− 4.9	− 2.9	− 0.8	− 3.8

[a] Estimated; actual readings valueless on account of reflowing. [b] Means for eighteen days.

Station 3. Newly sanded, thinly vined. Station 5. Peat with moss, heavily vined.

Highest and lowest readings are in italics.

TABLE 6.—COMPARISON OF MINIMUM TEMPERATURES IN OPEN AT SURFACE OF STATION 3, AND AT 5 INCHES AT STATION 5, THE WARMEST AND COLDEST PLACES ON THE MARSH, RESPECTIVELY; ALSO DAILY DIFFERENCES, MATHER, WIS., 1907.

Day of month.	May.[a]			June.			July.		
	Station 3—surface.	Station 5—5 inches.	Difference.	Station 3—surface.	Station 5—5 inches.	Difference.	Station 3—surface.	Station 5—5 inches.	Difference.
	°	°	°	°	°	°	°	°	°
1				34.0	*26.2*	− 7.8	59.5	55.9	− 3.6
2				38.3	27.9	−10.4	*38.8*	*27.9*	−10.9
3				52.9	46.9	− 6.0	47.2	36.2	*−11.0*
4				43.0	35.0	− 8.0	51.5	43.9	− 7.6
5				44.1	41.5	− 2.6	58.2	59.7	*+ 1.5*
6				[b] *33.8*	[b] 26.8	− 7.0	57.9	52.0	− 5.9
7				49.5	43.8	− 5.7	50.5	42.5	− 8.0
8				36.1	26.5	− 9.6	54.4	49.4	− 5.0
9				42.4	30.5	*−11.9*	58.8	51.9	− 6.9
10				53.7	53.0	*− 0.7*	50.0	41.0	− 9.0
11				44.0	38.4	− 5.6	62.0	60.1	− 1.9
12	37.3	35.0	−2.3	53.1	51.0	− 2.1	49.6	39.9	− 9.7
13	*56.5*	*58.9*	+2.4	42.6	32.4	−10.2	52.9	44.0	− 8.9
14	46.8	45.1	−1.7	39.3	29.6	− 9.7	61.0	56.8	− 4.2
15	39.0	36.9	−2.1	42.9	34.0	− 8.9	*68.9*	*67.1*	− 1.8
16	36.9	34.8	−2.1	53.5	45.5	− 8.0	54.0	45.3	− 8.7
17	39.0	33.0	−6.0	*66.6*	*62.5*	− 4.1	53.3	45.0	− 8.3
18	41.9	39.1	−2.8	57.7	48.9	− 8.8	51.2	42.6	− 8.6
19	35.0	31.0	−4.0	56.3	48.7	− 7.6	56.9	51.0	− 5.9
20	23.7	19.3	−4.4	51.0	42.4	− 8.6	58.1	51.3	− 6.8
21	*21.1*	*17.0*	−4.1	49.3	40.3	− 9.0	65.9	59.9	− 6.0
22	44.9	42.0	−2.9	62.3	59.6	− 2.7	[b] 63.8	61.9	− 1.9
23	45.0	43.7	−1.3	60.3	55.2	− 5.1	55.0	[b] 45.9	− 9.1
24	42.1	34.0	−8.1	54.9	49.5	− 5.4	62.2	[b] 57.1	− 5.1
25	45.0	43.8	−1.2	58.9	53.1	− 5.8	54.9	[b] 45.7	− 9.2
26	46.0	45.0	−1.0	49.0	45.7	− 3.3	52.8	[b] 42.1	−10.7
27	(c)	(c)		44.0	34.0	−10.0	47.5	40.0	− 7.5
28	(c)	(c)		45.0	35.2	− 9.8	58.1	53.2	− 4.9
29	35.9	29.3	−6.6	50.0	41.1	− 8.9	58.0	51.5	− 6.5
30	43.0	36.0	*−7.0*	55.4	47.4	− 8.0	50.3	41.6	− 8.7
31	48.3	45.9	−2.4				57.4	50.0	− 7.4
Means	40.4	37.2	−3.2	48.8	41.8	− 7.0	55.5	48.8	− 6.7

[a] Means for eighteen days.
[b] Estimated; actual readings valueless, on account of reflowing or heavy rains.
[c] Readings not obtained; marsh flooded.

Station 3. Newly sanded, thinly vined. Station 5. Peat with moss, heavily vined.
Highest and lowest readings are in italics.

TABLE 6.—COMPARISON OF MINIMUM TEMPERATURES IN OPEN AT SURFACE OF STATION 3, AND AT 5 INCHES AT STATION 5, THE WARMEST AND COLDEST PLACES ON THE MARSH, RESPECTIVELY; ALSO DAILY DIFFERENCES, MATHER, WIS., 1907—Continued.

Day of month.	August.			September.			October.		
	Station 3—surface.	Station 5—5 inches.	Differ-ence.	Station 3—surface.	Station 5—5 inches.	Differ-ence.	Station 3—surface.	Station 5—5 inches.	Differ-ence.
	°	°	°	°	°	°	°	°	°
1	55.1	44.0	−11.1	64.1	61.7	− 2.4	30.8	25.6	−5.2
2	49.0	40.9	− 8.1	53.9	45.5	− 8.4	46.1	46.7	+0.6
3	47.1	41.9	− 5.2	48.8	41.3	− 7.5	41.6	35.5	−6.1
4	43.1	*33.0*	−10.1	52.7	48.8	− 3.9	33.5	29.5	−4.0
5	61.3	58.0	− 3.3	46.7	41.3	− 5.4	36.3	30.3	−6.0
6	53.0	44.8	− 8.2	41.2	32.6	− 8.6	38.7	35.6	−3.1
7	59.0	54.0	− 5.0	56.5	55.5	− 1.0	*42.0*	38.0	−4.0
8	56.6	50.1	− 6.5	57.2	[a] 50.8	− 6.4	21.8	12.8	*−9.0*
9	54.0	48.0	− 6.0	39.0	33.7	− 5.3	34.6	34.0	−0.6
10	59.8	53.0	− 6.8	[a] 37.0	[a] 32.3	− 4.7	28.5	24.8	−3.7
11	*68.7*	*69.0*	*+ 0.3*	43.7	36.5	− 7.2	30.1	28.3	−1.8
12	49.7	41.0	− 8.7	43.3	37.0	− 6.3	28.4	25.9	−2.5
13	48.9	40.6	− 8.3	45.7	39.7	− 6.0	19.0	12.0	−7.0
14	52.3	45.0	− 7.3	56.5	54.9	− 1.6	17.7	12.4	−5.3
15	56.6	50.2	− 6.4	57.7	53.0	− 4.7	40.7	*41.5*	*+0.8*
16	62.1	58.6	− 3.5	*65.1*	*64.5*	*− 0.6*	33.1	29.4	−3.7
17	51.2	43.6	− 7.6	51.0	43.5	− 7.5	30.8	28.4	−2.4
18	54.8	46.7	− 8.1	59.0	56.1	− 2.9	23.6	20.7	−2.9
19	65.5	64.8	− 0.7	60.4	58.8	− 1.6	19.7	13.8	−5.9
20	46.6	34.8	−11.8	59.4	56.2	− 3.2	26.3	23.5	−2.8
21	48.4	35.6	*−12.8*	37.4	31.1	− 6.3	17.5	9.8	−7.7
22	*42.5*	33.6	− 8.9	[a] 30.3	19.7	*−10.6*	28.5	26.5	−2.0
23	54.0	46.1	− 7.9	41.7	39.0	− 2.7	24.5	18.8	−5.7
24	50.7	44.3	− 6.4	44.0	41.7	− 2.3	21.3	14.7	−6.6
25	42.7	33.3	− 9.4	[a] 27.2	20.6	− 6.6	23.6	21.5	−2.1
26	49.8	41.0	− 9.8	[a] 33.0	22.6	−10.4	16.8	9.3	−7.5
27	57.2	55.6	− 1.6	32.7	26.1	− 6.6	32.3	31.6	−0.7
28	54.0	50.5	− 3.5	38.4	36.9	− 1.5	*13.9*	*6.4*	−7.5
29	50.7	44.0	− 6.7	30.0	23.3	− 6.7	24.6	21.7	−2.9
30	62.9	62.6	− 0.3	*24.5*	*16.6*	− 7.9	36.2	35.7	−0.5
31	56.3	52.7	− 3.6	....	....	....	30.0	29.5	−0.5
Means	53.7	47.1	− 6.6	45.9	40.7	− 5.2	28.8	25.0	−3.8

TABLE 6a.—MONTHLY AND SEASONAL MEANS, STATION 3, SURFACE, AND STATION 5, 5 INCHES, MATHER, WIS. 1907.

	May.[b]	June.	July.	August.	September.	October.	Seasonal means.
	°	°	°	°	°	°	°
Station 3—surface	40.4	48.8	55.5	53.7	45.9	28.8	45.5
Station 5—5 inches	37.2	41.8	48.8	47.1	40.7	25.0	40.1
Difference	−3.2	−7.0	−6.7	−6.6	− 5.2	− 3.8	− 5.4

[a] Estimated; actual readings valueless, on account of reflowing or heavy rains.

[b] Means for eighteen days.

Station 3. Newly sanded, thinly vined.

Station 5. Peat with moss, heavily vined.

Highest and lowest readings are in italics.

Comparison of minimum temperatures at Station 1, in shelter, and on bog at Stations 3 and 5, Mather, Wis.—While the comparisons made in Tables 5 and 6 have been between the warmest and the coldest stations on the bog, the temperature in the shelter at Station 1 on the upland may properly be considered the standard, and a comparison between the thermometer therein and one in the open at the height of 5 inches at Station 5 and the one at the surface at Station 3 should be of special interest. Of course, the exposed minimum at Station 5 was much lower than the one in the shelter at Station 1, the average difference being 6.7°. (See Tables 7 and *7a.*) The least monthly average difference was 4.5° in May, and the greatest 8.3°, in October. The greatest daily difference in May was 12° on the 29th; in June, 11° on the 27th; in July, 12° on the 3d; in August, 14.2° on the 25th; in September, 11.6° on the 22d; in October, 14.6° on the 24th. With but few exception the temperature at Station 5 was lower than at Station 1 and markedly so on clear, cool nights. When the sky was overcast and the night windy the difference was much less.

The comparison between the shelter at Station 1 and the surface at Station 3, however, affords far different results. The temperature at Station 3 was, as a rule, only slightly below that in the shelter at Station 1, the seasonal average difference being 1.3°. In the summer the difference was very little, being only 0.1° and 0.2°, but it was greater in the spring and in the fall, especially in October when the average difference was 4.5°. At Station 5, as has been stated before, the difference was 8.3° for October. It is probable that these great differences in October were due to the number of comparatively cool nights which were gradually increasing in length and which afforded a longer period for radiation and consequent loss of heat from vegetation. The daily differences between the readings in the shelter at Station 1 and those in the open at Station 3, the sanded section, were often unimportant, and on many days there was a reversal, *the temperature actually reading higher over the sanded section in the bog, especially in the summer months. This inversion occurred on fourteen days in June, fourteen days in July, fifteen days in August, ten days in September, but in no instance in October.* These results—the comparatively high minimum temperatures at the surface of the sanded bog—really seem remarkable, and could hardly be believed unless great care had been taken in the observations. In this connection it is interesting to note that the minimum temperature in the shelter at Station 3 averaged for the season only 0.5° below that in the shelter at Station 1, while the minimum in the shelter at Station 5 averaged 3.1° below that in the shelter at Station 1. (See Table 18.) The advantages gained by sanding are still further emphasized by observations made at Berlin, Wis., where the exposed minimum at the surface of a sanded section during the month of September, 1906, actually averaged higher by 0.5° than the minimum in the shelter at Station 1, on adjoining hard land, while the exposed minimum at the 5-inch height at Station 5, the coldest point on the Berlin bog, averaged 9.5° lower than that in the shelter at Station 1. (Table 9.)

From the comparison of these observations made at Stations 3 and 5, at Mather, it should be apparent that a thinly vined, sanded, and well drained soil is a most important factor in conserving heat—in strong contrast with a heavily vined moss-covered surface which absorbs but little heat, and at the same time radiates rapidly.

TABLE 7.—COMPARISON OF MINIMUM TEMPERATURES IN SHELTER AT STATION 1, AND IN OPEN AT 5-INCH HEIGHT AT STATION 5, THE COLDEST PLACE ON THE MARSH, AND IN OPEN AT SURFACE AT STATION 3, THE WARMEST PLACE ON THE MARSH, ILLUSTRATING THE ADVANTAGES OBTAINED FROM SANDING, DRAINING, AND CULTIVATING, MATHER, WIS., 1907.

Day of month.	May.					June.				
	Station 1—shelter.	Station 5—5 inches above surface exposed.	Difference.	Station 3—surface exposed.	Difference—Stations 1 and 3.	Station 1—shelter.	Station 5—5 inches above surface exposed.	Difference.	Station 3—surface exposed.	Difference—Stations 1 and 3.
	°	°	°	°	°	°	°	°	°	°
1	....	....	....	....	....	36.0	*26.2*	− 9.8	4.0	− 2.0
2	....	....	....	....	....	38.7	27.9	−10.8	38.3	− 0.4
3	....	....	....	....	....	50.1	46.9	− 8.2	52.9	− 2.2
4	....	....	....	....	....	41.2	35.0	− 6.2	43.0	+ 1.8
5	....	....	....	....	....	44.4	41.5	− 2.9	44.1	− 0.3
6	....	....	....	....	....	*34.0*	32.5	− *1.5*	*33.8*	− 0.2
7	....	....	....	....	....	47.6	43.8	− 3.8	49.5	+ 1.9
8	....	....	....	....	....	36.0	26.5	− 9.5	36.1	+ 0.1
9	....	....	....	....	....	41.0	30.5	−10.5	42.4	+ 1.4
10	....	....	....	....	....	54.5	53.0	− 1.5	53.7	− 0.8
11	....	....	....	....	....	47.0	38.4	− 8.6	44.0	− 3.0
12	36.2	35.0	− 1.2	37.3	+ 1.1	52.8	51.0	− 1.8	53.1	+ 0.3
13	*64.0*	*58.9*	− 5.1	*56.5*	− *7.5*	43.7	32.4	−11.3	42.6	− 1.1
14	44.7	45.1	+ 0.4	46.8	+ 2.1	38.9	29.6	− 9.3	39.3	+ 0.4
15	36.0	36.9	+ 0.9	39.0	+ *3.0*	43.0	34.0	− 9.0	42.9	− 0.1
16	35.0	34.8	− 0.2	36.9	+ 1.9	53.8	45.5	− 8.3	53.5	− 0.3
17	40.0	33.0	− 7.0	39.0	− 1.0	*70.0*	*62.5*	− 7.5	*66.6*	− *3.4*
18	47.7	39.1	− 8.6	41.9	− 5.8	58.6	48.9	− 9.7	57.7	− 0.9
19	38.8	31.0	− 7.8	35.0	− 3.8	57.0	48.7	− 8.3	56.3	− 0.7
20	27.5	19.3	− 8.2	23.7	− 3.8	50.6	42.4	− 8.2	51.0	+ 0.4
21	*27.3*	*17.0*	−10.3	*21.1*	− 6.4	48.7	40.3	− 8.4	49.3	+ 0.6
22	45.0	42.0	− 3.0	44.9	− 0.1	61.4	59.6	− 1.8	62.3	+ 0.9
23	44.0	43.7	− 0.3	45.0	+ 1.0	60.2	55.2	− 5.0	60.3	+ 0.1
24	43.6	34.0	− 9.6	42.1	− 1.5	54.0	49.5	− 4.5	54.9	+ 0.9
25	45.0	43.8	− 1.2	45.0	0.0	57.8	53.1	− 4.7	58.9	+ 1.1
26	43.3	45.0	+ 1.7	46.0	+ 2.7	48.2	45.7	− 2.5	49.0	+ 1.2
27	a 32.5	(b)	....	(b)	....	45.0	34.0	−*11.0*	44.0	− 1.0
28	a 34.1	(b)	....	(b)	....	43.0	35.2	− 7.8	45.0	+ *2.0*
29	41.3	29.3	−*12.0*	35.9	− 5.4	51.0	41.4	− 9.6	50.0	− 1.0
30	44.6	36.0	− 8.6	43.0	− 1.6	58.0	47.4	−10.6	55.4	− 2.6
31	47.0	45.9	− 1.1	48.3	+ 1.3	....	....	....	....	....
Means	41.7	37.2	− 4.5	40.4	− 1.3	49.0	41.8	− 7.2	48.8	− 0.2

a Not included in average. b Under water.

Station 1. On upland.
Station 3. Thinly vined, newly sanded, and well drained section of marsh.
Station 5. Heavily vined, peat with moss, and poorly drained section of marsh.

Highest and lowest readings are in italics.

TABLE 7.—COMPARISON OF MINIMUM TEMPERATURES IN SHELTER AT STATION 1, AND IN OPEN AT 5-INCH HEIGHT AT STATION 5, THE COLDEST PLACE ON THE MARSH, AND IN OPEN AT SURFACE AT STATION 3, THE WARMEST PLACE ON THE MARSH, ILLUSTRATING THE ADVANTAGES OBTAINED FROM SANDING, DRAINING, AND CULTIVATING, MATHER, WIS., 1907—Continued.

Day of month.	July.					August.				
	Station 1—shelter.	Station 5—5 inches above surface exposed.	Difference.	Station 3—surface exposed.	Difference—Stations 1 and 3.	Station 1—shelter.	Station 5—5 inches above surface exposed.	Difference.	Station 3—surface exposed.	Difference—Stations 1 and 3.
	°	°	°	°	°	°	°	°	°	°
1	59.1	55.9	− 3.2	59.5	+ 0.4	55.0	44.0	−11.0	55.1	+ 0.1
2	*38.3*	*27.9*	−10.4	*38.8*	+ 0.5	45.8	40.9	− 4.9	49.0	+ 3.2
3	48.2	36.2	*−12.0*	47.2	− 1.0	48.1	41.9	− 7.2	47.1	− 1.0
4	51.0	43.9	− 7.1	51.5	+ 0.5	*38.9*	*33.0*	− 5.9	43.1	+ *4.2*
5	60.2	59.7	− 0.5	58.2	− 2.0	59.2	58.0	− 1.2	61.3	+ 2.1
6	58.2	52.0	− 6.2	57.9	− 0.3	54.0	44.8	− 9.2	53.0	− 1.0
7	50.7	42.5	− 8.2	50.5	− 0.2	57.0	54.0	− 3.0	59.0	+ 2.0
8	59.4	49.4	−10.0	54.4	− 5.0	55.0	50.1	− 4.9	56.6	+ 1.6
9	61.0	51.9	− 9.1	58.8	− 2.2	52.8	48.0	− 4.8	54.0	+ 1.2
10	50.0	41.0	− 9.0	50.0	0	59.0	[illegible]	− 6.0	59.8	+ 0.8
11	60.0	60.1	+ *0.1*	62.0	+ 2.0	*74.2*	*69.0*	− 5.2	*68.7*	− *5.5*
12	51.3	39.9	−11.4	49.6	− 1.7	52.7	41.0	−11.7	49.7	− 3.0
13	53.8	44.0	− 9.8	52.9	− 0.9	50.0	40.6	− 9.4	48.9	− 1.1
14	62.4	56.8	− 5.6	61.0	− 1.4	52.8	45.0	− 7.8	52.3	− 0.5
15	*68.3*	*67.1*	− 1.2	*68.9*	+ 0.6	56.1	50.2	− 5.9	56.6	+ 0.5
16	51.0	45.3	− 5.7	54.0	+ 3.0	61.2	58.6	− 2.6	62.1	+ 0.9
17	56.8	45.0	−11.8	53.3	− 3.5	52.2	43.6	− 8.6	51.2	− 1.0
18	50.4	42.6	− 7.8	51.2	+ 0.8	57.0	46.7	−10.3	54.8	− 2.2
19	56.0	51.0	− 5.0	56.9	+ 0.9	65.0	64.8	− 0.2	65.5	+ 0.5
20	61.0	51.3	− 9.7	58.1	− 2.9	43.0	34.8	− 8.2	46.6	+ 3.6
21	64.2	59.9	− 4.3	65.9	+ 1.7	47.0	35.6	−11.4	48.4	+ 1.4
22	64.0	61.9	− 2.1	[a] 63.8	− 0.2	43.0	33.6	− 9.4	*42.5*	− 0.5
23	52.8	[a] 45.9	− 6.9	55.0	+ 2.2	53.7	46.1	− 7.6	54.0	+ 0.3
24	64.0	[a] 57.1	− 6.9	62.2	− 1.8	54.1	44.3	− 9.8	50.7	− 3.4
25	52.6	[a] 45.7	− 6.9	54.9	+ 2.3	47.5	33.3	*−14.2*	42.7	− 4.8
26	49.0	[a] 42.1	− 6.9	52.8	+ *3.8*	50.7	41.0	− 9.7	49.8	− 0.9
27	45.0	40.0	− 5.0	47.5	+ 2.5	55.5	55.6	+ *0.1*	57.2	+ 1.7
28	58.9	53.2	− 5.7	58.1	− 0.8	58.0	50.5	− 7.5	54.0	− 4.0
29	56.7	51.5	− 5.2	58.0	+ 1.3	51.2	44.0	− 7.2	50.7	− 0.5
30	53.0	41.6	−11.4	50.3	− 2.7	64.0	62.6	− 1.4	62.9	− 1.1
31	57.6	50.0	− 7.6	57.4	− 0.2	58.3	52.7	− 5.6	56.3	− 2.0
Means	55.6	48.8	− 6.9	55.0	− 0.1	53.9	47.1	− 6.8	53.7	− 0.2

[a] Not included in average; affected by water.

Station 1. On upland.
Station 3. Thinly vined, newly sanded, and well drained section of marsh.
Station 5. Heavily vined, peat with moss, and poorly drained section of marsh.

Highest and lowest readings are in italics.

TABLE 7.—COMPARISON OF MINIMUM TEMPERATURES IN SHELTER AT STATION 1, AND IN OPEN AT 5-INCH HEIGHT AT STATION 5, THE COLDEST PLACE ON THE MARSH, AND IN OPEN AT SURFACE AT STATION 3, THE WARMEST PLACE ON THE MARSH, ILLUSTRATING THE ADVANTAGES OBTAINED FROM SANDING, DRAINING, AND CULTIVATING, MATHER, WIS., 1907—Continued.

Day of month.	September.					October.				
	Station 1—shelter.	Station 5—5 inches above surface exposed.	Difference.	Station 3—surface exposed.	Difference—Stations 1 and 3.	Station 1—shelter.	Station 5—5 inches above surface exposed.	Difference.	Station 3—surface exposed.	Difference—Stations 1 and 3.
	°	°	°	°	°	°	°	°	°	°
1	70.0	61.7	− 8.3	64.1	*−5.9*	33.0	25.6	− 7.4	30.8	− 2.2
2	53.1	45.5	− 7.6	53.9	+0.8	*51.5*	*46.7*	− 4.8	*46.1*	− 5.4
3	50.5	41.3	− 9.2	48.8	−1.7	45.6	35.5	−10.1	41.6	− 4.0
4	52.0	48.8	− 3.2	52.7	+0.7	41.0	29.5	−11.5	33.5	− 7.5
5	44.2	41.3	− 2.9	46.7	+1.5	41.2	30.3	−10.9	36.3	− 4.9
6	41.0	32.6	− 8.4	41.2	+0.2	44.0	35.6	− 8.4	38.7	− 5.3
7	54.0	55.5	*+ 1.5*	56.5	*+2.5*	49.5	38.0	−11.5	42.0	− 7.5
8	56.5	[a] 50.8	− 5.7	57.2	+0.7	22.8	12.8	−10.0	21.8	− 1.0
9	40.0	33.7	− 6.3	39.0	−1.0	40.0	34.0	− 6.0	34.6	− 5.4
10	38.0	[a] 32.3	− 5.7	[a] 37.0	−1.0	34.6	24.8	− 9.8	28.5	− 6.1
11	45.0	36.5	− 8.5	43.7	−1.3	34.6	28.3	− 6.3	30.1	− 4.5
12	48.0	37.0	−11.0	43.3	−4.7	29.3	25.9	− 3.4	28.4	− 0.9
13	49.9	39.7	−10.2	45.7	−4.2	24.6	12.0	−12.6	19.0	− 5.6
14	62.0	54.9	− 7.1	56.5	−5.5	22.5	12.4	−10.1	17.7	− 4.8
15	63.0	53.0	−10.0	57.7	−5.3	44.0	41.5	− 2.5	40.7	− 3.3
16	*66.6*	*64.5*	− 2.1	*65.1*	−1.5	35.5	29.4	− 6.1	33.1	− 2.4
17	53.0	43.5	− 9.5	51.0	−2.0	38.6	28.4	−10.2	30.8	− 7.8
18	57.9	56.1	− 1.8	59.0	+1.1	24.2	20.7	− 3.5	23.6	*− 0.6*
19	61.3	58.8	− 2.5	60.4	−0.9	27.3	13.8	−13.5	19.7	− 7.6
20	59.9	56.2	− 3.7	59.4	−0.5	27.5	23.5	− 4.0	26.3	− 1.2
21	37.9	31.1	− 6.8	37.4	−0.5	19.0	9.8	− 9.2	17.5	− 1.5
22	31.3	19.7	*−11.6*	[a] 30.3	−1.0	40.0	26.5	−13.5	28.5	*−11.5*
23	44.6	39.0	− 5.6	41.7	−2.9	29.6	18.8	−10.8	24.5	− 5.1
24	43.2	41.7	− 1.5	44.0	+0.8	29.3	14.7	*−14.6*	21.3	− 8.0
25	28.2	20.6	− 7.6	[a] 27.2	−1.0	27.6	21.5	− 6.1	23.6	− 4.0
26	34.0	22.6	−11.4	[a] 33.0	−1.0	18.9	9.3	− 9.6	16.8	− 2.1
27	33.7	26.1	− 7.6	32.7	−1.0	34.0	31.6	− 2.4	32.3	− 1.7
28	37.0	36.9	− 0.1	38.4	+1.4	*17.0*	*6.4*	−10.6	*13.9*	− 3.1
29	29.2	23.3	− 5.9	30.0	+0.8	3.25	21.7	−10.8	24.6	− 7.9
30	*27.5*	*13.6*	−10.9	*24.5*	−3.0	37.2	35.7	*− 1.5*	36.2	− 1.0
31	....	....	....	....	....	36.8	29.5	− 7.3	30.0	− 6.8
Means	47.1	40.7	− 6.4	45.9	−1.2	33.3	25.0	− 8.3	28.8	−4.5

[a] Estimated; actual readings valueless on account of reflowing or heavy rains.

Station 1. On upland.
Station 3. Thinly vined, newly sanded, and well drained section of marsh.
Station 5. Heavily vined, peat with moss, and poorly drained section of marsh.

TABLE 7a.—MONTHLY AND SEASONAL MEANS OF TABLE 7.

	May.[a]	June.	July.	August.	September.	October.	Seasonal means.
	°	°	°	°	°	°	°
Station 1—shelter	41.7	49.0	55.6	53.9	47.1	33.3	46.8
Station 5—5 inches above surface exposed	37.2	41.8	48.8	47.1	40.7	25.0	40.1
Difference	−4.5	−7.2	−6.8	−6.8	−6.4	−8.3	−6.7
Station 3—surface exposed	40.4	48.8	55.5	53.7	45.9	28.8	45.5
Difference—Stations 1 and 3	−1.3	−0.2	−0.1	−0.2	−1.2	−4.5	−1.3

[a] Means for eighteen days.

Highest and lowest readings are in italics.

Curves of air and soil temperatures at Stations 1, 3, and 5, Mather, Wis., 1907.—In order to indicate more graphically the relation existing between the air temperature and the temperature of the soil at the depth of 3 inches, and also between the soil temperatures at depths of 3 and 6 inches, Figures 21 and 22 have been prepared, showing curves for the season of 1907. The maximum temperature given is that recorded in the shelter at Station 1, equally applicable to Stations 3 and 5, and may be considered to represent in a measure the amount of insolation received from day to day. These graphs should supplement Tables 3, 5, 6, and 7.

From the beginning of the season and until midsummer the temperature of the soil at both Stations 3 and 5 rose gradually, apparently in direct proportion to the amount of heat which the different soils absorbed and conducted under the varying conditions of covering as regards vegetation, etc. The temperature of the soil at the 3-inch depth at Station 3, the sanded and thinly vined section, responded quickly to the various changes in insolation, and the range in soil temperature at this depth was relatively great from day to day, because of the slight depth at which the bulb of the soil thermometer was exposed, and also because of the good conductivity of the sanded soil. At the 6-inch depth at the same station the changes in temperature followed closely those at the 3-inch depth, but on account of the additional 3 inches in depth the changes from day to day were not so marked. At Station 5, peat soil with moss and dense vegetation, the temperature at 3 inches responded but slowly to changes in temperature of the air, because of the poor conductivity of the soil, and the fact that the dense growth of vegetation prevented the soil from absorbing much heat from the sun's rays. At the 6-inch depth the changes from day to day were even less. It is interesting here to note that, because of the dense vegetation and greater depth and the fact that the little heat received at the surface of the peat was conducted slowly to the soil beneath, the maximum heat of one day was not felt at the 6-inch depth at Station 5 until the day following. This lagging of the maximum heat is also noted at the 3-inch depth at the same station, but in a lesser degree, while almost invariably the maximum heat of one day was conducted on the same day to both depths at Station 3, the sanded section. These variations in soil temperature are shown graphically on May 19 and 30, June 7 and 19, July 6, August 11, and September 1. In this connection it may be noted that sudden falls in temperature of the air, as shown by the minimum temperature curves (Fig. 21), were felt but little at either depth at Station 5, and on July 21, while the temperature of the soil at both depths at Station 3 fell in response to a sudden decline in temperature of the air, the temperature of the soil at the depth of 6 inches at Station 5 was not influenced in the least, but even continued to rise gradually, the maximum heat recorded at the two first-named locations on July 20 not being felt at the 6-inch depth until the 22d, two days later.

Until the latter part of July the difference between the soil temperatures at the various depths was remarkably uniform. (Fig. 22.) From this time on until the end of the season the lines representing the seasonal march of soil temperature lose the relative positions which they occupy during the first part of the season. This is on account of the gradual approach of longer nights and shorter days with their attendant colder weather, so that more heat was lost from the sanded surface and less heat taken in, in proportion, than was lost and taken in by the *peat* soil. Hence, while a large amount of heat was lost each night from the *peat* soil, an even *larger* amount was lost from the *sanded surface itself*. On account of the greater susceptibility of the sand to changes in insolation as compared with that of the heavily vined peat soil, and because the heat in the peat which accumulates during the warm months is not lost as quickly as that in the sanded soil, we find the temperature of the soil on cold nights at both depths at Station 3 falling below the temperature of the soil at both depths at Station 5. These changes were apparent as early as August 1, when under the influence of a cool day, the soil temperature in the sanded section fell so much more than did the temperature in the peat soil, that the readings at all exposures were about the same, the temperature at 6 inches at Station 3 being 1° lower than at the corresponding depth at Station 5. Other such changes are well shown on August 20 and 26, September 3 and 21. On September 25, under the influence of continued cool weather, the temperature at both depths at Station 3 fell below that at both depths at Station 5 for the first time during the autumn. This is also noted on October 9, 12, 19, and 27.

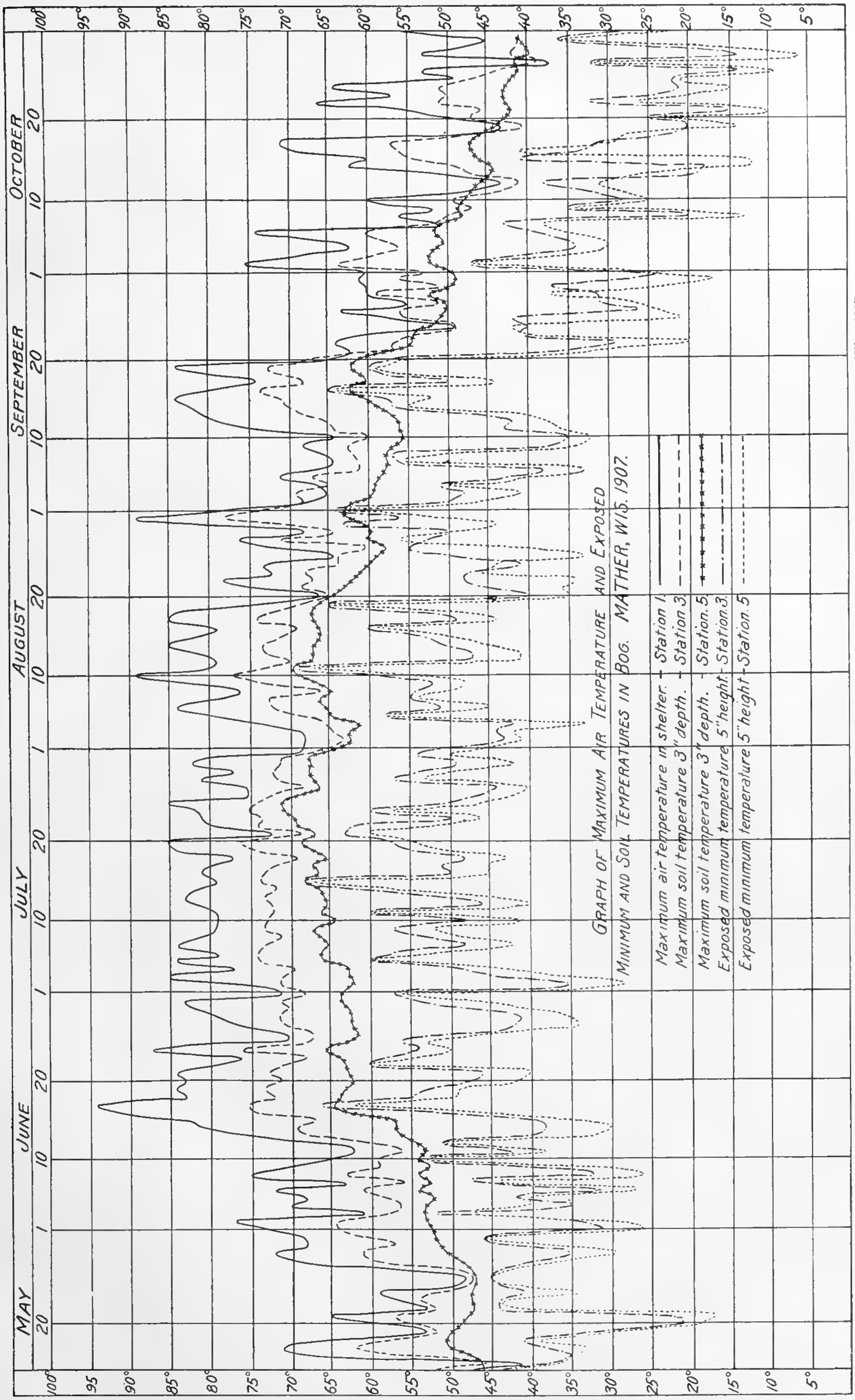

FIG. 21.—Graph of maximum and exposed minimum air temperatures and soil temperatures in bog, Mather, Wis., 1907.

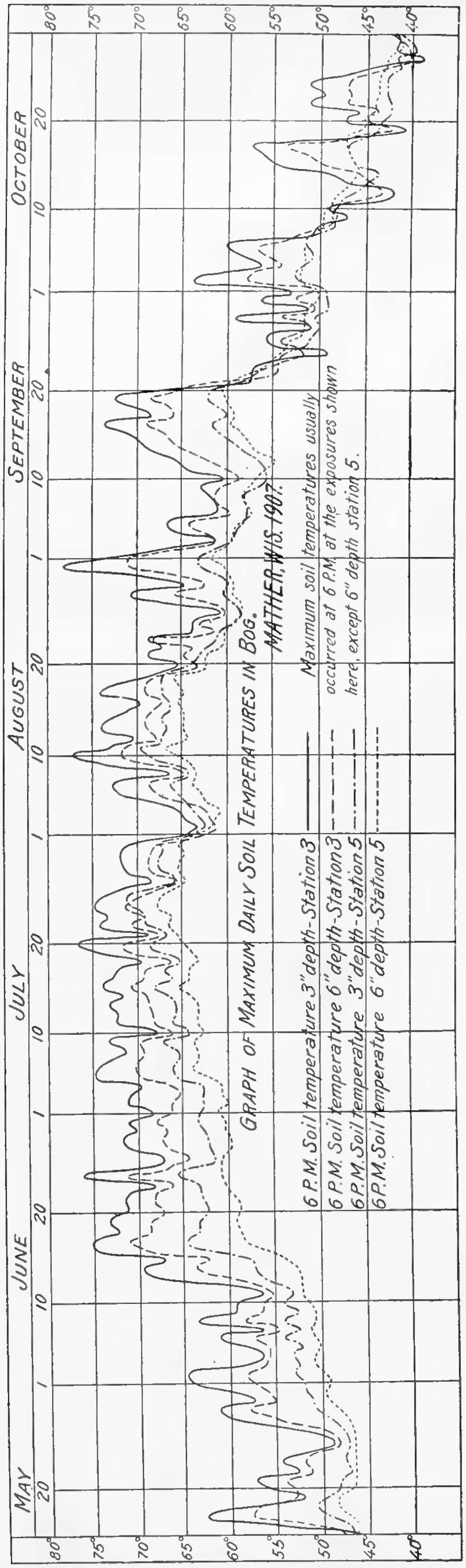

Fig. 22.—Graph of maximum daily soil temperatures in bog, Mather, Wis.

From a study of the graph, as shown in Figure 21, it is extremely interesting to note the tendency of the soil temperature during the months of August and September at the 3-inch depth at Station 5 to fall below that at the 6-inch depth at the same station, and it was noted to be actually lower for the first time on September 5. From the 20th on the readings at the former depth were almost continuously below those at the latter depth. In fact, by referring to Table 19, it will be found that the soil temperature at 6 inches at Station 5 began to gain on the temperature at 3 inches at the same station as early as July, and by the following amounts: July, 0.6°; August, 0.8°; September, 1.2°; October, 1.3°. This is because after a certain date, apparently late in July, the temperature of the soil at 3 inches began to decrease while that at 6 inches began to decrease also, but more slowly; so that during the month of October the temperature at the 6-inch depth was usually higher than at the 3-inch depth. This shows that while the peat soil at 6 inches under a thick growth of vegetation takes a longer time to become heated than at the three other locations, it retains its heat longer. The reason that generally during October the soil temperature at 3 inches at Station 5 was the lowest of the four exposures, with the readings at 6 inches between it and the 3-inch depth at Station 3, was probably because that, although it was not as easily influenced by the insolation as that at Station 3, still the temperature at 3 inches at Station 5 was not nearly as high even in midsummer, so that when cool weather approached it remained relatively low. On the other hand, the temperature at 3 inches at Station 3 was lower during cool, cloudy weather, and warmer during warm, sunshiny days; at the same time the temperatures at 6 inches took intermediate values because of their greater depth and consequent slower changes.

Minimum temperatures at the coldest and the warmest points on the bog at Berlin, Wis.—It is possible to make a comparison between the readings of the minimum thermometers exposed in the bog at places at Berlin, that are considered the warmest and the coldest referred to in previous paragraphs, and also to compare these readings with the readings of a thermometer in a shelter on hard land on the edge of the bog. The readings are found in Tables 8 and 9, and, although given only for the month of September, 1906, will serve to supplement the Mather

observations. Station 3 at Berlin was located in a newly sanded, thinly vined, and well drained section, similar to Station 3 at Mather, while Station 5 at Berlin was in the midst of a dense growth of vegetation, including vines, grasses, canebrakes, and ferns. In fact, this station was commonly called the "ferns." The uprights from the vines reached to a height of from 12 to 18 inches. It was a wild place, not resembling the conditions one would expect to find in a cultivated cranberry marsh; but cultivation was not practiced in reality at Berlin. Although it was the coldest point in the Berlin bog, the vegetation there was not similar to that prevailing at Station 5 at Mather. While moss, which is largely responsible for low night temperatures, was found at Mather, there was no indication of it whatever at Berlin, but the rank growth of vines and grasses because of generally poor cultivation was a fitting substitute.

It is not intended to make any detailed comparison between the readings of the thermometers at Stations 3 and 5 at Berlin at corresponding positions, but to compare the readings at the surface at Station 3 with those at the 5-inch height at Station 5, the warmest and the coldest exposures on the bog. However, in Table 8 are first given the readings of the minimum thermometers at both the surface and 5 inches, and the differences between the readings at each station; and in the lower column, are given the differences between the readings at the surface at Station 3 and the 5-inch height at Station 5. It is proper to state that the upper thermometer at Station 5 was not attached to any support, but was placed upon the vegetation which had been pressed down to a compact mass so that the thermometer rested 5 inches above the surface of the soil near the surface instruments. The lower thermometer was not shielded in the slightest degree by the upper one, but the radiation was freer at the higher elevation than from the lower thermometer which was obstructed laterally and obliquely by the dense vegetation. At Station 3 the higher thermometer was fastened to a post immediately above the thermometer which lay upon the ground.

The average difference for the month between the surface thermometer at Station 3 and the upper thermometer at Station 5 was 10°, and the maximum daily difference was 17.1° on the 4th. On only one day during the month was there an inversion of the usual conditions, September 2, and this was because there was water on the thermometers after a heavy rain. In fact, the readings of the instruments on that day should properly be excluded. These differences in temperature at Berlin were even greater than those observed at Mather.

The minimum thermometer in the shelter at Station 1 at Berlin, which was located on the edge of the bog, may be considered the standard as was that at Station 1 at Mather, and a comparison between the warmest and the coldest points on the bog at Berlin with this standard is important. For the month of September, 1906, the upper exposed thermometer at Station 5 averaged 9.5° below that in the shelter at Station 1, while a maximum difference of 16.4° occurred on September 3, and on sixteen days there were differences exceeding 10°. (Table 9.) In comparing the surface readings at Station 3 with the standard, it will be found that the exposed minimum over the sanded section actually averaged for the month higher by 0.5°. It, moreover, was higher on eighteen days, while on three days the readings were the same.

These results indicate the great advantage gained in draining, cultivating, and sanding a bog. *In spite of the fact that the thermometer at Station 3 was exposed at the surface of the soil in the open where the radiation was perfectly free, it averaged higher than the one in the shelter on hard land.* The conditions at Station 3 resemble approximately the improved conditions found in the Cape Cod marshes, while those at Station 5, on the other hand, are representative of the poorest conditions found in Wisconsin. It would seem as a result of these observations that the Wisconsin growers should feel obliged to adopt the Massachusetts methods.

Table 8.—Minimum Temperatures in the Open at Surface and at 5-Inch Height with Differences, for Station 3, Heavily Sanded, Thinly Vined, and Station 5, Peat, Heavily Vined, Dense Growth of Vegetation and Ferns, the Warmest and Coldest Parts of the Marsh, Respectively; also Difference Between Surface, Station 3, and 5-Inch Height, Station 5, Berlin, Wis., September, 1906.

Day of month.	Station 3.			Station 5.			Difference—Station 3, surface, and Station 5, 5 inches.
	Surface.	5 inches.	Difference.	Surface.	5 inches.	Difference.	
	°	°	°	°	°	°	°
1	51.5	45.5	−6.0	40.2	38.7	−1.5	−12.8
2	58.2	59.0	*+0.8*	[a] *63.0*	[a] *63.1*	+0.1	*+ 4.9*
3	52.0	43.5	−8.5	37.0	35.0	−2.0	−17.0
4	51.0	41.5	*−9.5*	37.5	33.9	−3.6	*−17.1*
5	45.0	35.9	−9.1	32.0	28.3	−3.7	−16.7
6	52.0	42.9	−9.1	39.8	36.0	*−3.8*	−16.0
7	55.0	50.0	−5.0	47.4	44.0	−3.4	−11.0
8	56.8	52.7	−4.1	49.0	46.2	−2.8	−10.6
9	59.0	54.9	−4.1	52.0	49.7	−2.3	− 9.3
10	64.5	60.0	−4.5	56.0	54.0	−2.0	−10.5
11	*66.0*	*64.6*	−1.4	60.0	60.7	*+0.7*	− 5.3
12	63.9	59.5	−4.4	56.6	54.8	−1.8	− 9.1
13	53.9	52.8	−1.1	52.3	50.8	−1.5	− 3.1
14	43.9	35.0	−8.9	32.6	28.8	*−3.8*	−15.1
15	48.1	44.7	−3.4	42.8	41.0	−1.8	− 7.1
16	56.0	55.4	−0.6	53.9	52.8	−1.1	− 3.2
17	62.3	59.0	−3.3	56.0	54.4	−1.6	− 7.9
18	64.0	60.0	−4.0	55.8	55.8	0.0	− 8.2
19	60.0	58.1	−1.9	52.9	52.0	−0.9	− 8.0
20	60.0	58.0	−2.0	58.0	57.5	−0.5	− 2.5
21	60.0	54.3	−5.7	50.9	49.0	−1.9	−11.0
22	55.1	48.5	−6.6	45.8	42.1	−3.7	−13.0
23	50.4	45.0	−5.4	42.4	38.9	−3.5	−11.5
24	41.0	34.0	−7.0	31.8	28.9	−2.9	−12.1
25	45.0	40.0	−5.0	38.0	34.3	−3.7	−10.7
26	54.8	53.8	−1.0	50.0	48.9	−1.1	− 5.9
27	40.3	*30.8*	*−9.5*	28.0	24.4	−3.6	−15.9
28	43.0	35.7	−8.3	31.5	28.0	−3.5	−15.0
29	54.3	53.5	−0.8	53.6	53.0	−0.6	− 1.3
30	*39.6*	31.0	−8.6	*27.6*	*23.0*	−3.7	−16.6
Means	53.6	48.7	−4.9	45.8	43.6	−2.2	−10.0

[a] Water on thermometers, and grass and vines very wet, due to rain.
Highest and lowest readings are in italics.

TABLE 9.—COMPARISON OF MINIMUM TEMPERATURES IN SHELTER, STATION 1, AND IN THE OPEN AT 5-INCH HEIGHT AT STATION 5, PEAT AND HEAVILY VINED, AND AT SURFACE AT STATION 3, THINLY VINED AND NEWLY SANDED, BERLIN, WIS., SEPTEMBER, 1906.

Day of month.	Station 1—Shelter.	Station 5—5 inches exposed.	Difference.	Station 3 Surface exposed.	Difference—Stations 1 and 3.	Day of month.	Station 1 Shelter.	Station 5 5 inches exposed.	Difference.	Station 3- Surface exposed.	Difference Stations 1 and 3.
	°	°	°	°	°		°	°	°	°	°
1	50.0	38.7	−11.3	51.5	+1.5	17	62.0	54.4	− 7.6	62.3	+0.3
2	65.7	[a] *63.1*	− 2.6	58.2	*−7.5*	18	64.0	55.8	− 8.2	64.0	0
3	51.4	35.0	*−16.4*	52.0	+0.6	19	60.0	52.0	− 8.0	60.0	0
4	46.8	33.9	−12.9	51.0	+4.2	20	58.6	57.5	− 1.1	60.0	+1.4
5	42.0	28.3	−13.7	45.0	+3.0	21	59.0	49.0	−10.0	60.0	+1.0
6	47.6	36.0	−11.6	52.0	*+5.6*	22	53.9	42.1	−11.8	55.1	+1.2
7	56.0	44.0	−12.0	55.0	−1.0	23	50.3	38.9	−11.4	50.4	+0.1
8	57.4	46.2	−11.2	56.8	−0.6	24	38.4	28.9	− 9.5	41.0	+3.4
9	56.1	49.7	− 6.4	59.0	+3.1	25	47.0	34.3	−12.7	45.0	−2.0
10	64.5	54.0	−10.5	64.5	0	26	56.4	48.9	− 7.5	54.8	−1.6
11	*69.0*	60.7	− 8.3	*66.0*	−3.0	27	*36.0*	24.4	−11.6	40.3	+4.3
12	62.9	54.8	− 8.1	63.9	+1.0	28	41.1	28.0	−13.1	43.0	+1.9
13	54.0	50.8	− 3.2	53.9	−0.1	29	53.9	53.0	− *0.9*	54.3	+0.4
14	41.3	28.8	−12.5	43.9	+1.4	30	38.0	*23.0*	−15.0	*39.6*	+1.6
15	51.9	41.0	−10.9	48.1	−3.8						
16	57.9	52.8	− 5.1	56.0	−1.9	Means	53.1	43.6	− 9.5	53.6	+0.5

[a] Water on thermometer, and grass and vines very wet, due to rain.
Highest and lowest readings are in italics.

Minimum temperatures over dry and moist sand, Stations 3 and 4, Berlin, Wis.—In order to further supplement the extensive observations made at Mather, a comparison was made between the surface minimum thermometers at Berlin, at Stations 3 and 4, dry and wet sand, for September, 1906. This comparison was made because data of the kind desired were not available at Mather, the sanded sections there being all comparatively dry. Both these stations were located in the thinly vined section, and there was apparently no difference in the character of the two stations, except that one was much wetter than the other. (See Table 10.) The temperature at the surface at Station 4 averaged 2.4° lower than that at the surface at Station 3, and there was an extreme difference of 7.3° on September 30, when the thermometer at Station 3 registered 39.6°, and the one at Station 4, 32.3°. *On the following day, October 1 (not included in this table), the minimum at Station 3 registered 35.8°, and at Station 4, 27.3°, the difference being 8.5°. It was on this date that the berries were frozen generally in the bog except in the dry sanded section.* On only one day did the thermometer at Station 3 register lower than the one at Station 4. The increased amount of moisture at Station 4 is solely responsible for the relatively low temperature readings, on account of the heat lost in the evaporation at the surface. While the reading of 64° on September 2 is included in the table and in the averages, it is not consistent with the other readings, and was due to water on the bulb of the instrument after a heavy rain.

TABLE 10.—MINIMUM TEMPERATURES IN THE OPEN AT SURFACES OF STATIONS 3 AND 4, WITH DIFFERENCES, BERLIN WIS., SEPTEMBER, 1906.

Day of month.	Station 3.	Station 4.	Difference.	Day of month.	Station 3.	Station 4.	Difference.	Day of month.	Station 3.	Station 4.	Difference.
	°	°	°		°	°	°		°	°	°
1	51.5	47.8	−3.7	12	63.9	62.1	−1.8	23	50.4	47.1	−3.3
2	58.2	[a] 64.0	*+5.8*	13	53.9	53.0	−0.9	24	41.0	37.4	−3.6
3	52.0	48.0	−4.0	14	43.9	37.7	−6.2	25	45.0	42.7	−2.3
4	51.0	48.0	−3.0	15	48.1	47.0	−1.1	26	54.8	52.8	−2.0
5	45.0	43.2	−1.8	16	56.0	56.5	+0.5	27	40.3	33.1	−7.2
6	52.0	48.1	−3.9	17	62.3	60.8	−1.5	28	43.0	38.0	−5.0
7	55.0	52.1	−2.9	18	64.0	63.0	−1.0	29	54.3	53.4	−0.9
8	56.8	56.0	−0.8	19	60.0	57.9	−2.1	30	*39.6*	*32.3*	*−7.3*
9	59.2	59.4	+0.2	20	60.0	59.0	−1.0				
10	64.5	64.3	−0.2	21	60.0	56.1	−3.9	Means	53.6	51.2	−2.4
11	*66.0*	*65.0*	−1.0	22	55.1	51.3	−3.8				

[a] Water on thermometer, and grass and vines very wet, due to rain.
Both stations thinly vined and heavily sanded, but Station 3, dry sand, and Station 4, wet sand.
Highest and lowest readings are in italics.

Minimum temperatures over peat bogs, heavily vined and thinly vined, Berlin, Wis., September, 1906.—In Tables 8 and 9 appear the readings of exposed minimum thermometers located at Station 5, in the ferns at Berlin, the coldest point in the Berlin bog. As stated above, the vegetation was very rank there. Station 2 at Berlin resembled Station 5 in its peat soil and want of good drainage, but it had in the spring of 1906 been thoroughly weeded, so that the vegetation was thin. Stations 2 and 5, then, may therefore well represent respectively thinly vined and densely vined locations. The record of the exposed minimums for September, 1906, at an elevation of 5 inches above the surface, Table 11, shows that Station 5 averaged 3.4° lower than Station 2. A maximum difference of 6.6° occurred on September 27, and if we exclude the readings of September 2, when water was on the bulb of the thermometer at Station 5, after a heavy rain, there is not a single instance in which the minimum at Station 2 was lower than the one at Station 5. The great differences in temperature are due entirely to weeding, the soil in the thinly vined section during the growing season being much warmer than a soil covered with dense vegetation. Radiation, however, should be just as free from a *thinly vined peat* soil as from one heavily vined.

It is as important to cultivate as it is to practice drainage. Of course it is impossible to determine absolutely the advantage in exact degrees gained by cultivation, draining, or sanding. While there is an average difference of 3.4°, as shown by Table 11, between the minimum thermometers in the thinly vined and the heavily vined sections, a difference of 2.4°, as shown by Table 10, between the minimum thermometers on wet and on dry sand, a difference of 1.7° between thermometers on peat and sanded bogs, both thinly vined, and a difference of 2.2° between the surface and 5 inches, it is obvious why an average difference of 10°, as shown by Table 8, can exist between a minimum thermometer exposed at the most favorable location as far as drainage, sanding, and cultivating are concerned, and another in a most unfavorable location, an unsanded peat section with a very dense growth of vegetation, and poor drainage. It is not strange, therefore, that in a bog where there is a variation in the conditions of sanding, draining, and cultivation, the range in minimum temperature is considerable, and that a portion of a bog is seriously injured by frost, while another portion completely escapes. It should be apparent why the experiment station at Cranmoor, Wis., where intensive cranberry growing is practiced, does not require reflowing of its bog on many cold nights in order to escape injury, when the crop of an unimproved bog might be completely wiped out unless protected by reflowing. For the same reason, the Cape Cod growers, on account of the excellent condition of their marshes, are seldom forced to use water for protection except in the late autumn.

TABLE 11.—MINIMUM TEMPERATURES IN THE OPEN AT 5-INCH HEIGHT, AT STATIONS 2 AND 5, WITH DIFFERENCES BERLIN, WIS., SEPTEMBER, 1906.

Day of month.	Station 2—5-inch.	Station 5—5-inch.	Difference.	Day of month.	Station 2—5-inch.	Station 5—5-inch.	Difference.	Day of month.	Station 2—5-inch.	Station 5—5-inch.	Difference.
	°	°	°		°	°	°		°	°	°
1	41.6	38.7	−2.9	12	57.4	54.8	−2.6	23	43.8	38.9	−4.9
2	59.3	[a] *63.1*	*+3.8*	13	53.0	50.8	−2.2	24	32.5	28.9	−3.6
3	39.5	35.0	−4.5	14	33.0	28.8	−4.2	25	38.7	34.3	−4.4
4	38.9	33.9	−5.0	15	44.5	41.0	−3.5	26	52.8	48.9	−3.9
5	33.1	28.3	−4.8	16	54.9	52.8	−2.1	27	31.0	24.4	*−6.6*
6	40.8	36.0	−4.8	17	57.3	54.4	−2.9	28	31.9	28.0	−3.9
7	47.6	44.0	−3.6	18	57.6	55.8	−1.8	29	53.6	53.0	−0.6
8	50.0	46.2	−3.8	19	58.0	52.0	−6.0	30	*28.8*	*23.0*	−5.8
9	52.4	49.7	−2.7	20	58.0	57.5	−0.5				
10	57.4	54.0	−3.4	21	51.4	49.0	−2.4	Means	47.0	43.6	−3.4
11	*64.0*	60.7	−3.3	22	47.0	42.1	−4.9				

[a] Water on thermometer, and grass and vines very wet, due to rain.

Station 2. Peat bog, thinly vined.
Station 5. Peat bog, heavily vined, with dense growth of vegetation and ferns.

Highest and lowest readings are in italics.

Minimum temperatures over peat bog and sanded bog, thermometers exposed at 5 inches above the surface, at Cranmoor, Mather, and Berlin.—Having made a comparison between the exposed minimums in various portions of the same bog at both Mather and Berlin, it is interesting to note how the readings vary in different bogs, for the season or a portion of the season, when the minimum thermometers are exposed in the vines over different soils at the height of 5 inches above the surface. In Table 12 we have a comparison between Cranmoor,[a] Mather, and Berlin for the months of August and September, 1906, at certain selected stations over peat and sanded bogs. The locations in each marsh were respectively the coldest and the warmest points, although it should be understood that the exposures of the thermometers given were at an elevation of 5 inches above the ground, the minimums, of course, registering higher at the surface where the radiation was less free. The sanded surfaces at the three stations closely resembled each other, while the exposures in the peat bog were over moss at Cranmoor and Mather and in the ferns at Berlin, there being no moss at the latter station. The vegetation was dense, however, in all three peat bogs, it being densest at Berlin. The average daily and the average monthly readings at any particular station are in themselves of little consequence in the discussion of Table 12, as there may be a variation in temperature because of the difference in geographical location. The average readings at corresponding locations at Cranmoor, Mather, and Berlin for the two months did not vary materially, but it is with the differences between the exposed minimums over the peat and the sanded bogs in which we are especially interested. For the two months the temperature over the sanded bog averaged higher than over the peat, as follows: Cranmoor, 5.3°, Mather, 4.4°, and Berlin 5.4°; the greatest daily difference was 11° at Cranmoor on August 30 and at Mather on September 15, and 19° at Berlin on August 11. At no time did the minimum over the peat register higher than that over the sand at any one of the three stations, with the single exception of September 2 at Berlin, when the instrument in the peat bog was affected by water, after a heavy rain. There were several dates, however, invariably on cloudy nights, when there was no difference between the readings of the instruments over the peat and the sand; but, of course, on these nights the temperature was high and there was no danger from frost.

In 1907 and 1908 data are available for the season at Cranmoor and Mather only, the Berlin station having been discontinued. It did not seem necessary to publish the tables for these two years. The most important features, however, were as follows: At Cranmoor in 1907 the differences averaged greatest during the summer months of July and August, 6.7° and 6.6°, respectively, while at Mather the greatest average monthly difference was 4.2° in September, this being 0.1° higher than the average for August. The greatest difference at Cranmoor on any one day was 12° on June 27, while the greatest difference at Mather was 8° on September 2 and 3 and October 5. In 1908 the average difference was 4.5° at Cranmoor and 4° at Mather, and the greatest difference on any one day occurred on August 5, 11° at Cranmoor, and at Mather the greatest difference, 8°, occurred on seven different days.

[a] Observations over sanded bog made at Cranmoor Experiment Station and those over peat at the Gaynor-Blackstone marsh immediately adjoining.

TABLE 12.—MINIMUM TEMPERATURES IN OPEN OVER PEAT BOG WITH DENSE VEGETATION, AND IN VINES OVER SANDED BOG, BOTH AT THE HEIGHT OF 5 INCHES, THE LATTER REPRESENTING BEST RESULTS FROM SANDING, DRAINING, AND CULTIVATING AT CRANMOOR, MATHER, AND BERLIN, WIS., AUGUST AND SEPTEMBER, 1906.

[P. indicates peat bog; S. indicates sanded surface; Diff. indicates excess of temperature of sanded surface over that of the peat bog.]

Day of month.	August, 1906.									September, 1906.								
	Cranmoor.			Mather.			Berlin.			Cranmoor.			Mather.			Berlin.		
	P.	S.	Diff.	P.	S.	Diff.	P.	S.	Diff.	P.	S.	Diff.	P.	S.	Diff.	P.	S.	Diff.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	47	54	+ 7	55	57	+ 2	45	56	+11	38	46	+ 8	38	44	+ 6	39	46	+ 7
2	53	55	+ 2	55	57	+ 2	52	56	+ 4	*61*	61	*0*	55	64	+ 9	*63*	59	*− 4*
3	55	61	+ 6	55	59	+ 4	57	63	+ 6	32	43	*+11*	35	43	+ 8	35	43	*+ 8*
4	48	56	+ 8	48	54	+ 6	50	52	+ 2	35	42	+ 7	36	40	+ 4	34	41	+ 7
5	65	65	*0*	64	64	*0*	66	66	*0*	32	41	+ 9	33	40	+ 7	28	36	*+ 8*
6	46	53	+ 7	48	53	+ 5	41	54	+13	37	45	+ 8	36	42	+ 6	36	43	+ 7
7	59	60	+ 1	58	60	+ 2	56	62	+ 6	42	50	+ 8	44	49	+ 5	44	50	+ 6
8	57	64	+ 7	59	62	+ 3	60	64	+ 4	47	52	+ 5	47	53	+ 6	46	53	+ 7
9	63	65	+ 2	64	66	+ 2	61	64	+ 3	47	54	+ 7	48	53	+ 5	50	55	+ 5
10	55	62	+ 7	60	64	+ 4	55	63	+ 8	53	60	+ 7	56	60	+ 4	54	60	+ 6
11	46	54	+ 8	51	57	+ 6	48	67	*+19*	58	*62*	+ 4	*63*	*65*	+ 2	61	*65*	+ 4
12	47	50	+ 3	44	49	+ 5	45	61	+16	60	*62*	+ 2	60	61	*+ 1*	55	60	+ 5
13	43	52	+ 9	47	52	+ 5	39	45	+ 6	49	51	+ 2	48	49	*+ 1*	51	53	+ 2
14	46	54	+ 8	48	53	+ 5	44	50	+ 6	28	36	+ 8	31	34	+ 3	29	35	+ 6
15	45	53	+ 8	45	50	+ 5	44	50	+ 6	47	49	+ 2	40	51	*+11*	41	45	+ 4
16	50	57	+ 7	51	56	+ 5	49	57	+ 8	59	59	*0*	58	*65*	+ 7	53	55	+ 2
17	55	60	+ 5	54	59	+ 5	62	65	+ 3	58	61	+ 3	57	60	+ 3	54	59	+ 5
18	59	61	+ 2	55	60	+ 5	54	58	+ 4	58	*62*	+ 4	58	62	+ 4	56	60	+ 4
19	60	64	+ 4	58	62	+ 4	58	58	*0*	56	57	+ 1	50	56	+ 6	52	58	+ 6
20	59	65	+ 6	63	67	+ 4	64	69	+ 5	54	55	+ 1	54	55	*+ 1*	58	58	0
21	64	*68*	+ 4	64	68	+ 4	65	*70*	+ 5	52	56	+ 4	49	55	+ 6	49	54	+ 5
22	64	67	+ 3	64	67	+ 3	60	64	+ 4	41	49	+ 8	44	49	+ 5	42	48	+ 6
23	64	*68*	+ 4	*65*	*69*	+ 4	61	61	*0*	37	45	+ 8	41	46	+ 5	39	45	+ 6
24	59	60	+ 1	60	60	*0*	60	61	+ 1	34	42	+ 8	38	42	+ 4	29	34	+ 5
25	*68*	*68*	*0*	*65*	*69*	+ 4	66	67	+ 1	35	42	+ 7	38	43	+ 5	34	40	+ 6
26	65	67	+ 2	62	63	+ 1	*68*	68	*0*	40	43	+ 3	40	42	+ 2	49	54	+ 5
27	33	*38*	+ 5	*31*	*a 40*	*+ 9*	*30*	*38*	+ 8	26	33	+ 7	28	34	+ 6	24	*31*	+ 7
28	35	42	+ 7	34	a 42	+ 8	36	44	+ 8	26	33	+ 7	31	36	+ 5	28	36	*+ 8*
29	44	52	+ 8	52	56	+ 4	48	52	+ 4	51	54	+ 3	36	39	+ 3	53	54	+ 1
30	*30*	41	*+11*	36	42	+ 6	36	46	+10	*17*	*29*	+12	*25*	*28*	+ 3	*23*	*31*	*+ 8*
31	34	44	+10	36	42	+ 6	38	44	+ 6	......	......	......	......	......	......	......	......	......
Means	52.2	57.4	+5.2	53.3	57.3	+4.0	52.2	57.9	+5.7	43.7	49.1	+5.4	43.9	48.7	+4.8	43.6	48.7	+5.1

a Water on thermometer, from rain.
Highest and lowest readings are in italics.

TABLE 12*a*.—MEANS OF TABLE 12.

	August.	September.	Means.
	°	°	°
Cranmoor:			
Peat bog	52.2	43.7	47.9
Sanded surface	57.4	49.1	53.2
Difference	+ 5.2	+ 5.4	+ 5.3
Mather:			
Peat bog	53.3	43.9	48.6
Sanded surface	57.3	48.7	53.0
Difference	+ 4.0	+ 4.8	+ 4.4
Berlin:			
Peat bog	52.2	43.6	47.9
Sanded surface	57.9	48.7	53.3
Difference	+ 5.7	+ 5.1	+ 5.4

Readings of exposed minimums at various elevations over bog and upland, Stations 2 and 9, Mather, Wis.—In the preceding pages there have been discussed the variations in temperature at various locations at the surface and at the height of 5 inches, and the connection existing between these temperatures and the temperature of the soil at the point of exposure. Excepting the minimum thermometers that were exposed in the shelters at Stations 1 at both Mather and Berlin, no reference has previously been made in this paper to the reading of an instrument higher than 5 inches above the surface.

In order to supplement the comparison of exposed minimum thermometers at the surface and 5 inches above, readings were made at Mather of instruments at Stations 2 and 9 placed as follows: Surface, 2½ inches, 5 inches, 7½ inches, 10 inches, 12 inches, 15 inches, and 36 inches above the surface. The character of these stations of course differs radically, Station 2 being located in the bog over sphagnum moss, while Station 9 was in the garden on the upland where the surface was comparatively clean and the soil a sandy loam. The difference in elevation between the two stations is about 15 feet. The results would have answered the purpose better had both the stations selected for this comparison been located on the bog. Daily, monthly, and seasonal averages appear in Tables 13, 13*a*, 14, 14*a*.

At Station 2 the minimum temperature averaged lowest for the entire season at the 5-inch height, the average being 40.1°. The temperature gradually increased thence upward and downward, being 41.8° at the surface and 43.2° at the 36-inch height, the surface reading therefore averaging 1.7° higher than at 5 inches and 1.4° lower than at 36 inches. In every month the average temperature was highest at 36 inches, with a secondary maximum at the surface. In May and June the temperature averaged slightly lower at 2½ inches than at 5 inches. For the entire season the temperature at 5 inches averaged only 0.2° below that at 2½ inches.

At Station 9 on the upland the average difference between the thermometers was not so great. The temperature at 2½ inches averaged lowest, 44.5°, instead of at 5 inches, as on the bog, but the difference was very slight between these two elevations—0.1°. The surface thermometer averaged highest, 45.5°, but there was only 1° difference on an average between the two extremes, while the average surface reading was 0.6° higher than at 36 inches. The average for the entire season fairly represents the conditions prevailing each month, the highest in each case occurring at the surface and the lowest at 2½ inches.

While at Station 2 the minimum thermometer was usually the lowest at either 2½ inches or 5 inches above the surface, and the temperature averaged higher for each month and the season at 36 inches than at the surface, yet on clear, cool nights, when radiation was the freest, the exposed minimum at 36 inches usually registered lower than at the surface. Moreover, on the coolest nights the difference between the exposed minimum at the surface and the 5-inch height was the greatest, occasionally exceeding 6°, as in October. (See Table 2.) On warm nights, however, almost without exception, the temperature at 36 inches registered considerably higher than at the surface, the maximum difference occurring on June 17, 6.7°, a partly cloudy night. On that date the surface thermometer was 62.1°, the one at 36 inches 68.8°, and at 5 inches 62.9°, this reading being higher than at the surface, and the lowest reading occurring at 2½ inches, 62°. At Station 9, of course, the variation was not so great, but it is interesting to note that while the average temperature at this station at the surface was higher than at 36 inches, and this fact was most pronounced on cold, clear nights, nevertheless, on warm nights the reverse was the case, the temperature at 36 inches almost invariably being higher than at the surface; or, in other words, at both stations, on clear, cool nights the thermometers at the 36-inch height usually registered lower than at the surface, and on warm nights the thermometers at 36 inches usually registered higher than at the surface, it being understood, however, that on both cool and warm nights the *lowest* temperature at both Stations 2 and 9 occurred neither at the surface nor at 36 inches, but at some point between the two, usually at 2½ or 5 inches.

On June 17, referred to above, when at Station 2 the surface thermometer registered 62.1°, and at 36 inches 68.8°, the readings at similar exposures at Station 9 were 67.1° and

67.3°, respectively, the upper thermometer at Station 2 on the bog actually reading higher by 1.5° than the one at Station 9 on the upland. On August 10, when the surface instruments at Stations 2 and 9 registered, respectively, 52.6° and 53.1°, the readings at 36 inches were, respectively, 57.8° and 51.8°, the one on the bog therefore registering 6° higher than the one on the upland.

It is important to note that at both Stations 2 and 9 there is an abrupt change in temperature between the surface and 2½ inches, the readings of the surface instruments being kept up by the conduction of heat from the ground, although unequally. Above 2½ inches the change at Station 9 is gradual. The average difference between the readings at 15 inches and 36 inches was only 0.1°, while at Station 2 on the bog the difference was 2.1°. Moreover, at Station 2 the average range for the season was 3.1°, from the minimum of 40.1° at 5 inches to the maximum of 43.2° at 36 inches. At Station 9 the average range for similar exposures was only 0.3°, from a minimum of 44.6° at 5 inches to a maximum of 44.9° at 36 inches. However, the extremes at Station 9, as has been stated before, were at the surface and 2½ inches, 45.5° and 44.5°, respectively, the range being but 1°. Where the minimum thermometers were placed directly one above another, as at Stations 2 and 9, it is obvious that the thermometer at 2½ inches is shielded as much by the six thermometers above as the one at the surface by the seven thermometers; but, nevertheless, the radiation amidst vegetation should be freer as the elevation increases. The lower down the thermometers are the more the radiation from them is interfered with, laterally and obliquely, by the surrounding vegetation. A thermometer or leaf elevated above the ground loses its heat more rapidly than if it rests upon the surface, because in the former case there is likely to be freer radiation in all directions; moreover, the heat conducted from the soil beneath affects the thermometer or leaf resting upon the surface and prevents its temperature from falling as low as it would if located a few inches above. Of course colder air, being heavier, gradually sinks to lower levels, but this process is very slow, while the processes of radiation and conduction may continue active. The problem is a complicated one, as many factors are involved, such as humidity, wind velocity, condition of the sky, barometric pressure, length of night, general temperature conditions, the temperature and composition of the soil, and its moisture and the character of its covering. It is quite difficult, however, to explain why the exposed minimum was almost uniformly lower at a few inches above the surface, except on the theory that the surface thermometer receives heat from the soil beneath. In any case, these results are important, as they show approximately the variation in minimum temperature to which vegetation in the bogs is subjected.

TABLE 13.—MINIMUM TEMPERATURES IN OPEN AT ALL ELEVATIONS AT STATION 2, OVER SPHAGNUM MOSS ON THE MARSH, MATHER, WIS., 1907.

Day of month.	May.[a]								June							
	Surface.	2½ inches.	5 inches.	7½ inches.	10 inches.	12 inches.	15 inches.	36 inches.	Surface.	2½ inches.	5 inches.	7½ inches.	10 inches.	12 inches.	15 inches.	36 inches.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1									30.3	*27.8*	*27.9*	*28.0*	28.8	28.3	*28.8*	32.3
2									30.4	29.6	29.4	29.8	29.8	29.0	30.1	32.8
3									50.0	52.2	53.0	53.0	53.0	52.8	53.8	54.0
4									36.0	35.4	35.2	35.3	35.9	35.5	36.4	38.0
5									36.7	37.6	38.0	38.8	39.1	38.9	40.0	40.9
6									*30.1*	28.0	*27.9*	*28.0*	*28.0*	*27.9*	28.9	*29.3*
7									43.0	44.0	44.8	45.0	45.3	45.0	46.0	46.5
8									30.2	28.0	27.9	28.1	28.5	28.0	29.0	30.8
9									34.3	32.8	32.9	32.8	33.0	32.8	33.9	36.0
10									52.0	53.0	53.3	53.1	53.0	52.8	53.8	53.8
11									40.2	38.9	39.1	39.5	39.8	40.0	41.1	43.8
12	32.5	34.9	35.2	35.4	35.9	34.7	35.0	36.1	50.9	50.4	50.5	50.5	50.5	50.4	50.2	51.9
13	*61.0*	*59.6*	*60.0*	*60.2*	*60.0*	*59.5*	*59.5*	*61.0*	35.0	34.4	34.4	34.7	35.0	35.9	36.0	39.3
14	45.9	45.0	44.5	44.9	44.9	43.9	44.0	44.8	32.3	31.4	31.0	31.1	31.1	31.0	32.0	35.0
15	37.5	36.5	36.3	36.0	36.0	35.0	35.1	35.7	37.0	35.0	35.0	35.0	35.3	35.3	36.1	37.8
16	34.3	34.0	34.1	34.0	34.0	33.0	34.9	34.1	47.8	46.0	46.0	46.1	46.1	46.0	47.0	49.2
17	32.8	32.0	32.4	33.0	34.0	33.4	34.3	37.4	*62.1*	*62.0*	*62.9*	*63.9*	*65.0*	*65.3*	*66.8*	*68.8*
18	32.8	31.6	32.0	33.0	34.0	33.9	35.1	39.5	51.0	49.5	49.6	49.8	49.8	49.8	50.6	53.8
19	29.8	28.1	28.2	28.3	29.1	28.6	29.3	33.3	48.0	46.5	46.8	47.0	47.4	47.5	48.9	51.0
20	*20.9*	*18.0*	*18.0*	*18.3*	*18.9*	*18.0*	*18.2*	*20.2*	43.8	42.3	42.3	42.2	42.5	42.5	43.1	45.5
21	23.9	20.9	21.0	21.0	21.2	20.6	20.5	22.1	43.0	41.5	41.4	41.4	41.6	41.5	42.0	44.0
22	41.0	43.1	44.0	44.0	44.0	43.0	43.0	44.0	59.8	58.5	59.0	59.2	59.5	59.5	60.0	60.7
23	44.0	43.8	43.9	43.9	43.9	42.9	43.0	44.0	55.0	53.7	53.9	54.0	54.1	54.1	55.1	57.8
24	36.9	38.4	40.2	41.0	41.3	40.8	41.9	42.3	50.8	49.4	49.6	49.9	50.0	50.1	51.0	53.2
25	44.8	44.0	44.0	44.0	44.0	43.0	43.0	43.7	54.6	52.9	53.0	53.0	53.1	53.4	54.0	55.3
26	45.5	45.3	45.2	45.0	45.0	44.2	44.0	45.0	42.4	41.0	40.9	41.1	41.8	42 1	43.1	44.5
27	29.4	27.0	27.0	27.4	27.8	27.0	27.3	29.0	38.0	35.8	35.2	35.4	35.9	36.0	36.5	38.6
28	29.2	27.4	27.3	27.9	28.0	27.4	27.8	32.4	39.6	36.8	36.7	36.8	37.0	37.0	37.3	39.0
29	30.6	29.4	29.8	30.0	30.5	30.1	30.5	35.2	44.8	42.5	42.6	42.8	43.0	43.0	43.7	46.7
30	36.8	35.9	36.0	36.6	36.9	36.3	36.4	40.9	51.0	48.9	48.9	49.0	49.0	49.0	50.6	53.1
31	46.8	45.3	45.0	45.0	45.1	44.8	43.8	45.6								
Means	36.8	36.0	36.2	36.4	36.7	36.0	36.3	38.8	43.3	42.2	42.3	42.5	42.7	42.7	43.5	45.4

[a] Means for twenty days.

Highest and lowest readings are in italics.

TABLE 13.—MINIMUM TEMPERATURES IN OPEN AT ALL ELEVATIONS AT STATION 2, OVER SPHAGNUM MOSS ON THE MARSH, MATHER, WIS., 1907—Continued.

Day of month.	July.								August.							
	Surface.	2½ inches.	5 inches.	7½ inches.	10 inches.	12 inches.	15 inches.	36 inches.	Surface.	2½ inches.	5 inches.	7½ inches.	10 inches.	12 inches.	15 inches.	36 inches.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	54.0	51.6	52.0	52.8	54.3	54.9	55.9	56.4	51.3	47.7	47.0	47.0	46.9	46.9	47.0	49.7
2	*32.1*	*29.9*	*29.4*	*29.5*	*29.6*	*29.7*	*30.0*	*31.2*	44.4	40.0	39.1	39.4	39.5	39.7	39.9	42.0
3	38.5	38.6	38.5	38.7	38.9	39.0	39.8	42.1	43.0	40.5	40.0	40.1	40.3	40.4	40.6	42.9
4	47.2	44.4	44.7	44.7	44.8	44.9	45.0	46.9	35.9	34.6	34.1	*33.2*	*33.1*	*33.3*	*33.4*	*35.4*
5	59.0	59.0	59.4	59.5	60.0	60.0	60.5	60.5	58.0	58.0	57.9	58.0	58.0	58.0	58.0	58.4
6	56.1	52.6	52.8	52.9	53.0	53.0	54.8	56.0	49.4	46.8	46.0	46.0	46.0	46.1	46.2	49.0
7	47.8	43.7	43.3	43.8	44.0	44.0	44.3	46.2	51.0	48.7	48.2	48.1	48.2	48.5	49.3	53.0
8	50.9	47.6	47.0	47.7	47.8	48.0	49.0	53.0	54.2	51.6	51.0	51.0	50.5	50.8	50.9	53.4
9	55.0	51.4	51.0	51.0	51.3	51.7	52.2	55.7	52.0	49.0	48.9	49.2	49.0	49.4	49.6	52.0
10	46.7	42.8	42.3	42.5	42.8	43.0	43.2	46.0	52.6	54.5	54.6	54.5	54.5	54.9	54.4	57.8
11	62.9	60.7	60.2	59.9	60.0	60.0	60.0	60.1	*70.0*	*70.0*	*70.5*	*70.8*	*71.0*	*71.0*	*70.9*	*72.0*
12	46.2	42.2	42.3	42.1	42.0	42.1	42.4	45.1	44.9	40.3	40.1	40.1	40.0	40.3	40.3	45.2
13	48.8	44.6	44.6	44.8	44.7	44.8	45.2	48.8	45.0	42.2	42.0	42.5	42.3	42.5	42.5	45.3
14	59.9	56.6	56.4	56.7	57.0	57.5	58.4	60.5	48.8	46.2	46.0	46.5	46.4	46.5	46.2	48.9
15	*67.1*	*67.4*	*67.8*	*67.9*	*68.0*	*68.0*	*68.1*	*68.2*	51.9	49.7	49.6	50.0	49.7	50.0	51.6	54.0
16	50.3	46.6	46.3	46.4	46.5	46.7	47.0	48.2	59.6	57.7	57.7	58.2	57.8	57.9	57.9	60.0
17	48.0	45.1	45.0	45.1	48.2	45.7	46.4	50.0	46.4	43.6	43.4	43.8	43.6	43.6	46.1	47.4
18	47.5	45.0	44.5	43.9	44.0	44.2	44.6	46.0	50.2	47.7	47.7	47.9	47.6	47.7	48.0	52.2
19	54.8	52.0	51.8	51.9	52.0	52.0	52.5	54.5	64.7	64.7	64.7	64.9	64.6	64.7	64.8	65.2
20	53.7	50.2	50.0	50.3	50.5	51.0	52.0	55.0	38.0	34.6	34.1	34.7	34.6	34.3	35.0	38 5
21	63.4	60.5	60.2	60.1	60.0	60.2	61.0	62.9	39.5	36.2	35.7	36.5	36.3	36.4	36.6	40.3
22	60.2	57.0	57.3	57.4	57.9	58.5	59.4	61.7	*35.6*	34.6	33.9	34.6	34.2	34.3	34.5	37.3
23	a 49.1	50.2	48.9	49.0	48.7	48.8	49.1	50.0	50.0	47.6	47.2	48.0	47.6	47.7	48.0	52.3
24	a 60.3	59.0	58.7	58.8	58.8	58.9	59.7	61.7	44.0	41.6	41.0	41.7	41.5	41.8	42.5	46.5
25	a 48.9	51.1	49.5	49.3	49.2	49.4	50.0	50.9	35.9	*33.2*	*32.7*	34.0	34.0	34.6	35.0	39.0
26	a 45.3	42.8	42.3	42.4	42.5	42.8	43.0	45.0	45.0	42.8	42.5	43.4	43.4	43.6	43.9	46.5
27	44.4	41.3	41.0	40.6	40.6	40.8	41.0	42.2	57.0	57.0	56.5	57.0	56.5	56.4	56.7	56.6
28	59.0	55.0	55.3	55.4	55.7	56.0	56.5	58.5	51.4	50.0	49.9	50.7	50.6	50.9	51.0	53.6
29	52.0	48.2	48.1	48.1	48.0	48.1	49.0	52.0	46.0	44.5	43.7	44.6	44.6	44.8	44.9	47.6
30	49.0	45.1	45.0	44.9	44.5	44.4	44.5	47.9	62.6	62.5	62.3	62.7	62.6	62.7	62.5	63.8
31	53.0	42.9	48.5	48.5	48.4	48.6	48.9	51.0	53.5	52.5	52.4	52.7	52.7	53.0	53.5	55.8
Means	52.0	49.2	49.2	49.2	49 4	49.6	50.1	52.1	49.4	47.4	47.1	47.5	47.3	47.5	47.8	50.4

Estimated; actual readings valueless on account of heavy rains.

Highest and lowest readings are in italics.

TABLE 13.—MINIMUM TEMPERATURES IN OPEN AT ALL ELEVATIONS AT STATION 2, OVER SPHAGNUM MOSS ON THE MARSH, MATHER, WIS., 1907—Continued.

Day of month.	September.								October.							
	Surface.	2½ inches.	5 inches.	7½ inches.	10 inches.	12 inches.	15 inches.	36 inches.	Surface	2½ inches.	5 inches.	7½ inches.	10 inches.	12 inches.	15 inches.	36 inches.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	
1	62.3	61.2	60.9	61.7	61.7	61.8	61.8	65.0	29.0	27.7	26.6	27.8	27.8	28.3	28.0	29.9
2	43.3	42.2	41.9	43.0	43.5	43.9	44.7	48.2	*46.2*	*45.6*	*45.1*	*46.2*	*46.2*	*46.4*	*46.0*	*51.0*
3	41.5	40.6	40.5	41.6	41.8	42.4	42.7	44.8	38.0	36.6	35.7	36.8	37.0	37.0	37.0	39.0
4	45.7	44.8	44.7	45.8	46.0	46.5	46.8	49.0	29.6	27.9	27.3	28.5	28.7	29.1	29.6	33.1
5	37.5	36.0	35.5	36.9	37.1	37.6	38.2	41.1	29.0	27.7	27.0	28.4	28.7	29.5	29.3	33.0
6	35.5	34.3	33.4	34.6	34.6	34.7	35.2	37.0	35.7	34.3	33.7	34.7	35.1	35.5	35.5	41.5
7	55.2	55.3	54.9	55.5	55.0	55.4	55.3	55.8	39.0	38.1	37.4	38.5	38.6	38.7	38.6	42.6
8	55.9	55.8	55.6	56.3	54.9	56.0	56.0	56.6	20.0	17.5	15.9	17.2	17.5	17.6	17.8	19.2
9	33.0	31.0	30.3	31.6	31.7	32.2	32.6	36.4	33.1	32.8	32.8	34.5	35.0	35.5	35.0	39.0
10	31.4	30.9	30.3	31.4	31.5	31.7	31.7	34.0	27.7	26.1	25.0	26.4	26.5	26.7	26.5	29.3
11	39.0	37.5	37.4	38.5	38.7	39.2	39.3	41.9	28.5	27.3	26.0	27.0	27.3	27.5	27.2	30.6
12	38.8	37.3	36.6	37.7	37.7	38.0	38.1	42.5	24.0	23.3	22.7	24.0	24.4	24.5	24.3	26.5
13	41.7	40.2	40.3	40.5	40.6	40.9	41.0	43.1	19.6	16.8	15.8	17.0	17.4	17.6	17.7	19.0
14	56.4	57.4	57.3	58.0	58.0	58.3	58.3	59.5	19.8	17.1	15.6	16.8	17.3	17.4	17.5	18.9
15	58.4	53.7	53.6	54.6	54.7	55.0	55.0	57.6	40.1	39.8	39.4	40.6	40.9	41.3	41.0	42.0
16	*64.6*	*64.6*	*64.2*	*64.8*	*64.7*	*64.6*	*64.5*	*65.3*	31.7	30.2	29.4	30.6	31.0	31.4	31.4	33.1
17	46.0	44.1	43.6	44.5	44.6	44.7	44.6	47.4	29.9	28.3	27.4	28.4	28.7	28.7	28.5	30.0
18	57.0	56.3	56.0	56.2	56.4	56.4	56.5	55.0	19.4	18.3	17.6	19.2	19.6	19.3	19.6	20.5
19	58.6	58.4	58.0	58.9	59.0	59.0	59.0	60.3	21.1	18.1	17.9	19.0	19.4	19.6	19.8	21.0
20	56.4	56.5	57.2	57.5	57.3	57.3	57.7	59.0	25.0	22.6	21.9	23.3	23.6	23.8	23.7	25.3
21	31.6	30.3	29.5	30.5	30.7	31.0	30.8	33.9	18.0	14.6	13.2	14.2	14.6	14.7	14.7	15.0
22	25.0	23.5	22.7	23.9	24.3	24.5	24.7	27.5	30.0	30.5	30.7	32.5	33.0	33.4	33.5	35.4
23	38.2	37.4	37.0	38.5	38.9	39.4	39.7	42.9	24.6	22.4	21.9	23.5	23.6	23.7	23.6	24.0
24	41.0	40.8	40.3	40.7	41.0	41.0	40.5	42.3	21.1	18.8	17.7	19.4	19.8	20.3	20.6	22.5
25	23.3	20.6	19.5	21.0	21.3	21.5	22.0	23.0	20.7	17.6	17.2	18.9	19.5	19.7	19.4	21.9
26	27.2	25.5	24.7	26.0	26.0	26.4	26.5	28.5	16.5	13.5	12.5	13.8	14.0	14.5	14.5	14.9
27	29.2	27.7	27.0	28.1	28.4	28.6	28.7	30.0	29.2	29.3	29.4	30.4	30.2	30.0	29.5	29.8
28	36.0	35.2	34.6	35.4	35.5	35.8	35.7	37.5	*15.4*	*11.7*	*10.0*	*11.5*	*12.3*	*12.5*	*12.5*	*13.2*
29	27.3	25.6	24.6	28.8	25.9	26.0	26.4	27.3	26.9	26.6	25.7	26.3	26.7	26.9	26.5	26.4
30	*22.5*	*20.0*	*18.8*	*19.9*	*20.2*	*20.5*	*20.7*	*22.5*	35.0	35.3	34.8	35.9	35.9	36.0	35.5	35.6
31	......	......	......	......	......	......	......	......	30.0	30.2	29.4	30.4	31.0	31.5	31.5	32.6
Means	41.9	40.8	40.4	41.3	41.4	41.7	41.8	43.8	27.5	26.0	25.2	26.5	26.8	27.1	27.0	28.9

TABLE 13a.—MONTHLY AND SEASONAL MEANS OF MINIMUM TEMPERATURES IN OPEN AT ALL ELEVATIONS, STATION 2, MATHER, WIS., 1907.

	May.[a]	June.	July.	August.	September.	October.	Means.
	°	°	°	°	°	°	°
Surface	36.8	43.3	*52.0*	49.4	41.9	27.5	41.8
2½ inches	*36.0*	*42.2*	*49.2*	47.4	40.8	26.0	40.3
5 inches	36.2	42.3	*49.2*	*47.1*	*40.4*	*25.2*	*40.1*
7½ inches	36.4	42.5	*49.2*	47.5	41.3	26.5	40.6
10 inches	36.7	42.7	49.4	47.3	41.4	26.8	40.7
12 inches	*36.0*	42.7	49.6	47.5	41.7	27.1	40.8
15 inches	36.3	43.5	50.1	47.8	41.8	27.0	41.1
36 inches	*38.8*	*45.4*	*52.1*	*50.1*	*43.8*	*28.9*	*43.2*

[a] Means for twenty days.

Highest and lowest readings are in italics.

Table 14.—Minimum Temperatures in Open at all Elevations at Station 9, over Sandy Loam on the Upland, Mather, Wis., 1907.

Day of month.	May.[a]								June.							
	Surface.	2½ inches.	5 inches.	7½ inches.	10 inches.	12 inches.	15 inches.	36 inches.	Surface.	2½ inches.	5 inches.	7½ inches.	10 inches.	12 inches.	15 inches.	36 inches.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1									33.8	32.2	32.2	32.3	32.4	32.2	32.3	33.1
2									36.9	34.3	34.8	34.9	34.9	34.9	34.8	35.5
3									53.5	53.6	53.8	54.0	53.8	54.0	54.0	54.3
4									44.0	40.3	40.4	40.5	40.5	40.5	40.4	40.1
5									42.1	42.5	42.9	43.0	43.0	43.0	43.0	43.7
6									*34.7*	*31.4*	*31.5*	*31.7*	*31.7*	*31.7*	*31.2*	*31.4*
7									47.7	46.5	46.5	46.8	46.7	46.7	46.6	46.7
8									34.6	31.8	31.8	31.8	31.8	31.8	*31.2*	31.8
9									40.9	37.9	37.9	37.9	37.8	37.8	37.5	37.6
10									54.0	53.3	53.4	53.5	53.4	53.5	53.7	52.9
11									45.5	43.5	43.7	43.8	43.9	44.0	43.9	44.2
12	36.7	36.7	36.7	37.0	37.0	37.0	37.0	37.0	53.0	52.3	52.5	52.6	52.3	52.0	52.0	52.0
13	*57.9*	*59.8*	*59.8*	*60.5*	*58.7*	*58.5*	*60.5*	*60.9*	42.0	40.0	41.1	41.2	41.2	41.3	41.3	41.9
14	46.6	45.2	45.0	45.2	45.0	45.1	45.0	44.9	38.9	36.0	36.1	36.2	36.0	36.1	36.0	36.0
15	38.3	36.3	36.0	36.1	36.1	36.0	36.0	35.5	42.5	41.0	41.0	41.0	40.8	40.9	40.5	40.6
16	35.6	35.0	34.8	34.8	35.0	35.0	33.3	34.9	54.5	52.0	52.0	52.1	52.0	52.0	52.0	52.0
17	41.0	39.4	39.1	39.3	39.3	39.1	39.3	39.4	*67.1*	*66.4*	*66.5*	*66.4*	*66.8*	*67.9*	*66.9*	*67.3*
18	43.7	44.7	44.9	45.3	45.6	46.0	46.0	47.0	59.0	55.8	55.7	55.7	55.7	55.8	55.5	55.8
19	35.9	34.9	35.0	35.7	36.0	36.0	36.0	36.9	55.1	54.8	54.9	55.0	54.9	54.8	54.9	55.0
20	*24.9*	23.7	23.8	24.0	24.8	24.9	25.0	25.9	51.6	47.8	47.9	47.9	47.9	47.7	47.8	47.9
21	*24.9*	*22.9*	*23.0*	*23.1*	*23.1*	*23.1*	*23.0*	*23.8*	49.8	46.3	46.6	46.9	46.9	46.9	46.9	46.4
22	44.6	44.2	44.2	44.6	44.1	44.2	44.3	44.0	60.9	60.7	60.6	60.5	60.6	60.7	60.8	60.9
23	44.2	44.0	44.0	44.0	44.0	44.0	44.0	44.0	59.1	57.4	57.7	57.9	57.9	58.0	58.1	58.5
24	41.9	41.8	41.8	41.8	41.9	42.0	41.6	42.0	55.0	53.2	53.2	53.1	53.0	53.0	53.0	52.9
25	44.8	43.9	44.0	43.9	44.0	44.0	43.9	46.7	56.9	56.7	56.5	56.7	56.5	56.6	56.8	56.8
26	45.8	45.1	45.1	45.2	45.0	45.1	45.0	45.0	47.0	47.0	47.2	47.3	47.3	47.1	47.3	47.4
27	30.0	31.4	31.6	32.0	32.0	31.9	32.0	32.1	44.8	42.7	42.8	42.9	42.9	42.9	43.2	43.3
28	31.0	30.8	31.1	31.6	31.5	31.6	31.8	32.0	46.0	42.0	42.1	42.0	41.9	41.7	41.8	41.7
29	37.2	36.1	36.3	36.7	36.8	37.0	36.9	37.6	52.1	47.8	48.0	48.1	48.0	48.0	49.2	49.3
30	44.5	42.0	42.3	42.2	42.1	42.0	42.0	42.8	56.2	53.9	54.1	54.4	54.2	54.3	54.4	55.0
31	47.8	46.8	46.8	46.9	46.8	46.8	46.4	46.4								
Means	39.9	39.2	39.3	39.5	39.4	39.5	39.4	39.9	48.7	46.7	46.8	46.9	46.9	46.9	46.9	47.1

[a] Means for twenty days.

Highest and lowest readings are in italics.

TABLE 14.—MINIMUM TEMPERATURES IN OPEN AT ALL ELEVATIONS AT STATION 9, OVER SANDY LOAM ON THE UPLAND, MATHER, WIS., 1907—Continued.

Day of month.	July.								August.							
	Surface.	2½ inches.	5 inches.	7½ inches.	10 inches.	12 inches.	15 inches.	36 inches.	Surface.	2½ inches.	5 inches.	7½ inches.	10 inches.	12 inches.	15 inches.	36 inches.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	57.8	57.8	57.8	57.9	57.7	57.9	57.9	58.0	54.0	52.8	52.8	52.9	52.6	52.7	52.7	52.8
2	*38.3*	*33.7*	*33.9*	*34.2*	*34.5*	*34.7*	*34.8*	*35.0*	43.9	43.8	43.9	44.0	44.0	44.0	44.1	44.1
3	49.6	44.8	45.0	45.2	45.2	45.3	45.5	45.9	46.7	46.5	46.5	46.7	46.6	46.6	46.7	46.8
4	52.6	49.8	49.5	49.8	49.5	49.6	49.7	49.3	*38.7*	*37.2*	*37.7*	*37.6*	*37.6*	*37.4*	*37.5*	*37.2*
5	54.3	59.1	60.0	60.5	60.3	60.7	60.8	59.4	59.0	58.2	58.2	58.1	58.0	58.2	58.6	58.3
6	59.4	57.4	57.3	57.5	57.3	57.4	57.5	57.4	52.9	51.0	51.3	51.5	51.5	51.8	52.0	51.6
7	52.7	49.2	49.0	49.0	48.9	48.9	49.0	48.9	55.0	55.0	55.1	55.2	55.1	55.4	55.6	56.0
8	56.3	56.0	56.2	56.5	56.4	56.5	56.7	57.1	55.2	53.6	53.8	54.0	53.7	54.0	53.8	53.6
9	61.4	59.7	59.9	60.0	59.8	60.0	60.0	60.0	52.1	52.0	51.9	51.9	51.8	51.7	51.7	51.6
10	51.9	48.0	47.6	47.5	47.3	47.2	47.4	47.1	53.1	51.9	52.0	51.9	51.7	51.7	51.8	51.8
11	61.6	60.1	60.1	60.1	60.1	60.1	60.2	60.0	*71.1*	*71.0*	*70.9*	*71.0*	*71.3*	*71.5*	*71.6*	*72.0*
12	48.4	46.8	47.0	47.3	47.4	47.5	47.8	48.9	50.0	49.0	49.0	49.1	49.1	49.3	49.2	49.6
13	52.0	49.1	49.4	49.5	49.7	49.8	49.9	50.1	48.4	47.4	47.5	47.6	47.5	47.5	47.5	47.5
14	61.5	59.9	60.0	60.1	60.2	60.3	60.5	60.9	51.0	50.2	50.4	50.8	50.6	50.9	50.9	50.8
15	*68.0*	*68.0*	*68.0*	*68.0*	*67.9*	*68.0*	*68.0*	*68.3*	54.2	53.8	54.0	54.4	54.1	54.5	54.4	54.6
16	54.1	50.5	50.4	50.2	50.1	50.0	50.1	50.0	62.0	61.0	61.3	61.2	61.2	61.3	61.4	61.2
17	54.9	53.8	53.9	54.2	54.0	54.1	54.2	54.6	49.9	48.9	49.0	49.4	49.2	49.5	49.5	49.7
18	51.4	49.0	49.0	49.0	48.8	48.9	48.8	48.7	54.8	54.0	54.2	54.4	54.4	54.5	54.9	54.0
19	56.6	55.0	55.1	55.1	55.0	55.2	54.0	54.0	65.1	64.8	65.0	64.9	64.7	64.8	65.0	64.1
20	59.0	58.8	58.9	59.1	59.0	59.0	59.2	59.5	42.0	40.6	40.8	41.8	41.0	41.0	40.9	41.2
21	65.6	64.0	64.0	63.7	63.5	62.8	63.6	63.0	45.2	44.5	44.7	44.8	44.6	44.7	44.6	44.5
22	62.5	62.9	63.0	63.0	63.0	63.0	63.3	63.4	41.6	40.7	40.8	41.0	40.9	40.9	40.7	40.8
23	50.4	49.7	49.9	50.0	50.1	50.3	50.5	50.6	52.0	51.9	52.4	52.8	52.4	52.6	52.6	52.7
24	62.0	62.8	63.1	63.4	63.4	63.7	63.8	64.1	49.5	49.9	50.0	50.0	50.7	50.2	50.8	51.9
25	52.8	51.6	51.6	51.5	51.4	51.5	51.5	51.3	44.0	43.8	44.2	44.3	44.3	44.5	44.5	44.7
26	47.8	47.5	47.8	47.8	47.7	47.8	47.9	48.0	51.7	48.7	49.0	49.1	49.0	49.1	49.1	49.1
27	44.6	43.3	43.4	43.2	43.1	43.1	43.1	43.0	58.0	57.0	57.0	57.2	56.7	57.0	57.0	56.5
28	57.1	56.8	56.9	57.1	57.1	57.0	57.4	57.9	55.6	54.7	54.9	55.1	55.0	55.2	55.2	55.4
29	55.0	54.9	55.0	55.2	55.0	55.2	55.3	55.9	51.7	50.5	50.5	50.4	50.4	50.5	50.2	50.1
30	50.9	49.8	49.9	50.0	49.9	50.0	50.1	50.4	64.0	63.7	63.8	63.8	63.7	63.9	63.8	63.7
31	55.1	55.4	55.7	56.0	55.8	56.0	56.0	56.3	57.4	56.4	56.7	57.0	57.0	57.2	57.1	57.2
Means	55.0	53.7	53.8	53.9	53.8	53.9	54.0	54.1	52.6	51.8	51.9	52.0	51.9	52.1	51.8	52.1

Highest and lowest readings are in italics.

TABLE 14.—MINIMUM TEMPERATURES IN OPEN AT ALL ELEVATIONS AT STATION 9, OVER SANDY LOAM ON THE UPLAND, MATHER, WIS., 1907—Continued.

Day of month.	September.								October.							
	Surface.	2½ inches.	5 inches.	7½ inches.	10 inches.	12 inches.	15 inches.	36 inches.	Surface.	2½ inches.	5 inches.	7½ inches.	10 inches.	12 inches.	15 inches.	36 inches.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	*65.7*	*66.6*	*66.7*	*66.7*	*66.7*	*67.0*	*67.0*	*67.2*	33.8	32.2	32.3	32.4	32.4	32.2	32.4	32.1
2	51.0	51.3	51.4	51.6	51.6	51.6	51.7	51.7	*49.6*	*49.6*	*50.0*	*50.3*	*50.3*	*50.5*	*50.7*	*51.4*
3	48.9	48.8	48.9	49.0	48.9	49.1	49.0	49.0	44.4	43.5	43.6	43.6	43.6	43.5	43.7	43.4
4	52.0	51.8	52.0	52.2	51.8	52.1	52.0	51.9	37.7	38.3	38.4	38.6	38.6	38.6	38.6	38.9
5	43.3	43.5	43.6	43.6	43.5	43.5	43.5	43.5	38.0	38.7	39.0	39.3	39.4	39.4	39.3	39.6
6	40.4	39.4	39.4	39.4	39.4	39.4	39.2	39.1	42.1	41.6	41.8	42.3	42.4	42.5	42.8	43.6
7	56.0	55.6	55.6	55.7	55.5	55.7	55.6	53.5	46.1	45.0	45.3	45.5	45.5	45.6	45.6	45.7
8	56.9	56.6	56.7	56.7	56.7	56.6	56.6	56.5	22.5	20.0	19.8	19.8	19.7	19.7	19.6	19.5
9	38.6	38.2	38.4	38.5	38.4	38.3	38.3	38.4	36.4	37.2	37.5	37.7	37.7	37.9	38.0	38.5
10	38.7	36.8	36.8	36.9	36.7	36.7	36.7	36.5	31.6	31.2	31.5	31.7	31.8	31.8	31.9	32.0
11	45.7	45.0	45.4	45.5	45.5	45.5	45.5	45.5	33.0	33.6	33.7	33.8	33.8	33.8	33.9	34.0
12	44.6	44.7	44.8	44.9	45.0	45.0	45.0	45.4	27.4	28.0	28.0	28.4	28.3	28.2	28.2	28.4
13	47.3	46.3	46.3	46.4	46.3	46.5	46.4	46.4	21.5	21.6	21.6	21.6	21.6	21.8	21.7	21.7
14	56.5	56.7	57.4	57.2	57.5	57.9	58.1	57.3	21.7	18.8	18.9	19.3	19.3	19.3	19.3	19.3
15	56.6	56.8	57.5	57.2	57.6	57.9	58.0	56.8	42.2	42.5	42.6	42.6	42.6	42.7	42.8	42.8
16	65.0	64.7	64.8	64.8	64.7	65.0	65.0	65.0	36.4	35.5	35.5	35.5	35.5	35.4	35.5	35.0
17	52.4	50.3	50.4	50.5	50.4	50.5	50.4	50.1	34.4	33.8	34.2	34.4	34.4	34.4	34.4	34.6
18	58.1	57.7	57.7	57.8	57.6	57.6	57.7	57.3	23.2	23.0	23.0	23.2	23.1	23.0	23.0	23.0
19	60.3	60.0	59.9	60.0	59.7	60.3	60.2	60.1	23.8	22.7	23.0	23.6	23.6	23.6	23.6	23.7
20	57.3	58.4	58.6	58.8	58.7	58.3	58.6	58.8	25.4	25.7	25.8	26.1	26.0	26.1	26.0	26.1
21	36.7	35.1	35.3	35.5	34.6	35.5	35.5	35.6	18.4	15.6	15.6	16.2	16.2	16.2	16.2	15.8
22	28.0	27.8	27.8	28.1	28.3	28.0	28.2	28.6	34.4	31.9	35.7	36.3	36.4	36.4	36.7	37.3
23	42.2	42.2	42.4	42.5	42.5	42.5	42.6	42.6	26.6	26.5	26.6	26.8	26.8	26.8	26.9	27.0
24	42.2	42.3	42.4	42.4	42.3	42.4	42.6	41.5	23.4	23.0	23.2	23.3	23.3	23.4	23.5	24.0
25	26.4	26.2	26.3	26.4	26.4	26.4	26.5	26.5	24.6	25.3	25.3	25.5	25.5	25.5	25.6	25.7
26	31.2	29.3	29.3	29.4	29.3	29.4	29.4	29.5	16.7	14.8	14.8	14.8	14.8	14.8	14.7	14.6
27	32.6	31.5	31.6	31.6	31.4	31.6	31.5	31.4	32.6	32.8	33.2	33.4	33.3	33.3	33.4	33.1
28	38.0	37.9	38.0	38.2	38.1	38.2	38.2	38.0	*15.2*	*13.5*	*13.6*	*13.8*	*13.8*	*13.8*	*14.0*	*14.1*
29	29.2	28.6	28.6	28.7	28.6	28.6	28.5	28.3	29.9	28.8	29.0	29.0	29.1	29.1	29.0	28.9
30	*25.0*	*24.6*	*24.7*	*25.0*	*25.2*	*25.1*	*25.2*	*25.4*	36.7	36.6	36.7	36.7	36.6	36.4	36.6	36.1
31	......	......	......	......	......	......	......	......	33.9	34.0	34.3	34.3	34.4	34.4	34.5	34.7
Means	45.6	45.2	45.3	45.4	45.3	45.4	45.4	45.3	31.1	30.5	30.8	31.0	31.0	31.0	31.0	31.1

TABLE 14a.—MONTHLY AND SEASONAL MEANS OF MINIMUM TEMPERATURES IN OPEN AT ALL ELEVATIONS, STATION 9, MATHER, WIS., 1907.

	May.[a]	June.	July.	August.	September.	October.	Means.
Surface	*39.9*	*48.7*	*55.0*	*52.6*	*45.6*	*31.1*	*45.5*
2½ inches	*39.2*	*46.7*	*53.7*	*51.8*	*45.2*	*30.5*	*44.5*
5 inches	39.3	46.8	53.8	51.9	45.3	30.8	44.6
7½ inches	39.5	46.9	53.9	52.0	45.4	31.0	44.8
10 inches	39.4	46.9	53.8	51.9	45.3	31.0	44.7
12 inches	39.5	46.9	53.9	52.1	45.4	31.0	44.8
15 inches	39.4	46.9	54.0	51.8	45.4	31.0	44.8
36 inches	*39.9*	47.1	54.1	52.1	45.3	*31.1*	44.9

[a] Means for twenty days.

Highest and lowest readings are in italics.

Comparison of wind movement over upland and marsh, and effect on temperature, Mather, Wis., 1907.—Not as much variation in temperature occurred at Station 9 as at Station 2, because the former was on the upland where there was more breeze, which mixed the air at different elevations. On clear, cool, quiet nights the cold air settles gradually through gravity toward the surface of the earth, but if the night is windy, the air at different elevations is mixed together so that the temperature of the air over a considerable area is nearly uniform. The greatest difference locally is on a clear night when a calm prevails, so that there is no interference with the gradual settling of the cold, heavy air to the surface.

Of course the velocity of the wind is least near the surface of the earth, due to friction, and the velocity increases with the elevation. Anemometers placed on the upland and on the bog at Mather show that the variation, even for a slight elevation, is quite decided. (See Tables 15 and 15*a*.) The anemometer on the upland was located on the cupola of the warehouse, 32 feet 7 inches above the ground and 45 feet 10 inches above the level of the instrument on the marsh. (Fig. 16.) The mean hourly velocity of the wind on the upland for the five months, June to October, inclusive, was 9 miles, while on the marsh it was just half that amount, 4.5 miles. This proportion, moreover, was maintained for the various months. The highest average hourly movement for both exposures was from 12 to 1 p. m., it being 13.7 miles on the upland and 7.9 miles on the bog. The lowest average for any one hour was 6.3 miles on the upland between 2 a. m. and 3 a. m., while on the lowland the lowest was 2.3 miles, this occurring between 9 p. m. and 10 p. m., and also from midnight to 4 a. m. For some reason the average on the lowland was slightly higher between 10 p. m. and midnight, while on the upland there was a gradual decrease every hour from the maximum at 1 p. m. to the minimum at 3 a. m. The lowest hourly average movement in the individual months occurred in only one hour in each case. As a rule there was a falling off of the wind after the hour of greatest heat, the movement declining more rapidly in proportion over the bog than on the upland. Frequently at night an absolute calm prevailed on the bog.

On several mornings when there was a moderate to fresh wind velocity there was usually a difference of less than 2° between the extremes of the various thermometers at Station 2 on the bog. On August 19, when a fair breeze prevailed, this difference was only 0.6°. There were, on the other hand, many instances of nights of either light wind or of no wind, when a great variation occurred in the readings of the thermometers at different elevations, as on May 30, June 30, July 7 and 13, and October 14, the range at Station 2 being from 4° to 5°. When the wind over the bog was light or calm during the night, the variation in temperature was invariably greater than the average, and when there was a breeze at night the variation was less.

Because of the greater movement of the air with increased elevation, the temperature of the air over the upland did not vary as much as on the bog. While there was an average extreme difference of 3.1° between all the readings at Station 2 on the bog for the season, this difference at Station 9 on the upland amounted to only 1°. (Tables 13*a* and 14*a*.)

Table 15.—Average Hourly Wind Velocity on Upland and Marsh, Mather, Wis., 1907.

Hour of day.	June.		July.		August.		September.		October (30 days).		Means.	
	Upland.	Marsh.	Upland.	Marsh.	Upland.	Marsh.	Upland.	Marsh.	Upland.	Marsh.	Upland.	Marsh.
1 a. m.	6.4	1.9	*5.2*	1.8	5.9	2.0	7.3	2.9	7.0	2.8	6.4	*2.3*
2 a. m.	6.5	1.9	5.5	1.8	*5.7*	2.0	7.7	3.1	7.1	2.8	6.5	*2.3*
3 a. m.	*6.1*	*1.8*	*5.2*	1.9	6.1	2.0	*7.1*	*2.7*	7.1	3.0	*6.3*	*2.3*
4 a. m.	6.2	1.9	5.5	1.7	*5.7*	*1.9*	7.6	3.1	7.5	2.8	6.5	*2.3*
5 a. m.	6.6	2.1	5.6	1.9	*5.7*	2.3	8.1	3.6	7.5	3.2	6.7	2.6
6 a. m.	6.7	2.9	5.4	2.5	5.9	2.6	8.1	3.7	7.4	3.1	6.7	3.0
7 a. m.	7.8	4.0	6.0	3.4	7.2	3.5	8.1	3.9	7.4	3.3	7.3	3.6
8 a. m.	10.1	5.3	7.1	4.0	8.1	4.6	9.1	5.0	8.8	4.3	8.6	4.6
9 a. m.	10.8	6.1	7.3	4.7	10.0	5.8	10.8	6.0	11.3	6.1	10.0	5.5
10 a. m.	11.9	6.4	9.2	5.5	11.4	6.6	12.9	7.1	13.0	7.4	11.3	6.6
11 a. m.	12.5	6.9	10.1	6.0	12.0	6.9	14.2	8.3	13.1	7.6	12.4	7.1
12 noon	13.1	7.1	10.4	6.4	12.5	7.5	14.6	8.6	13.4	8.0	12.8	7.3
1 p. m.	12.9	7.2	11.1	6.7	*14.0*	*8.2*	*15.8*	*8.7*	*14.7*	*8.7*	*13.7*	*7.9*
2 p. m.	*13.4*	*7.3*	11.4	6.8	13.3	7.9	14.8	8.5	13.6	8.1	13.5	7.7
3 p. m.	13.0	7.0	*11.8*	*7.0*	12.9	7.5	14.3	8.1	13.9	8.1	13.2	7.5
4 p. m.	12.8	7.0	11.5	6.9	13.1	7.6	13.2	7.5	13.5	7.5	12.8	7.3
5 p. m.	12.3	6.5	11.2	6.3	11.6	6.7	11.2	6.4	11.1	6.1	11.5	6.4
6 p. m.	10.3	5.5	9.4	5.3	9.5	5.3	8.5	4.5	8.3	3.7	9.2	5.9
7 p. m.	8.2	3.9	6.9	3.4	8.0	3.5	7.3	3.0	7.9	3.1	7.7	3.4
8 p. m.	6.8	2.3	5.3	1.9	6.9	2.9	7.5	3.1	7.7	3.1	6.8	2.7
9 p. m.	6.6	2.1	5.5	*1.6*	6.6	2.3	7.8	3.2	7.7	3.1	6.8	2.5
10 p. m.	6.7	2.0	5.9	1.9	6.3	2.0	7.5	2.8	7.7	3.0	6.8	*2.3*
11 p. m.	6.9	2.3	5.9	2.2	6.3	2.3	7.6	3.2	*6.9*	2.8	6.7	2.6
12 midnight	6.7	2.1	5.8	2.2	6.3	2.3	7.7	3.0	7.2	*2.6*	6.7	2.4
Means	9.2	4.3	7.7	3.9	8.8	4.4	9.9	5.0	9.6	4.8	9.0	4.5

Anemometer on warehouse (upland), 32 feet 7 inches above ground.
Anemometer on marsh, 4 feet 7 inches above ground (Station 4).
Anemometer on warehouse, 50 feet 5 inches above surface of marsh at Station 4.
Difference between elevations of anemometers, 45 feet 10 inches.

Table 15*a*.—Average Velocity of the Wind, by Months, on Marsh and Upland, together with Average for Five Months, Mather, Wis., 1907.

	June.	July.	August.	September.	October.	Means.
Upland	9.2	7.7	8.8	9.9	9.6	9.0
Marsh	4.3	*3.9*	4.4	*5.0*	4.8	4.5

Highest and lowest readings are in italics.

As has been said before, the air over the bog was often light and even calm on clear, cool nights. When the breeze freshened, the temperature invariably rose near the surface of the bog, although it might at the same time fall on the upland. At Station 5, under such conditions, on July 27, 1906, at Mather, Wis., following a fall in temperature, a rise of 9° occurred between 2.45 a. m. and 3.45 a. m., while during a portion of that period the temperature at Station 1 fell 4°, followed by a rise of the same amount. When the breeze subsided after 4 a. m., the temperature fell again both on the upland and the moorland. With the freshening of the wind, the air over the moorland at different elevations evidently became mixed together and a rise in temperature was the result. Over the upland, 15 feet higher, although a fall in temperature occurred with the first freshening of the wind, the temperature began to rise later, after the breeze had continued for an hour, and the air at different strata for a considerable elevation had become mixed together. (Figure 23 shows the thermograph traces and the wind velocity on both upland and lowland.)

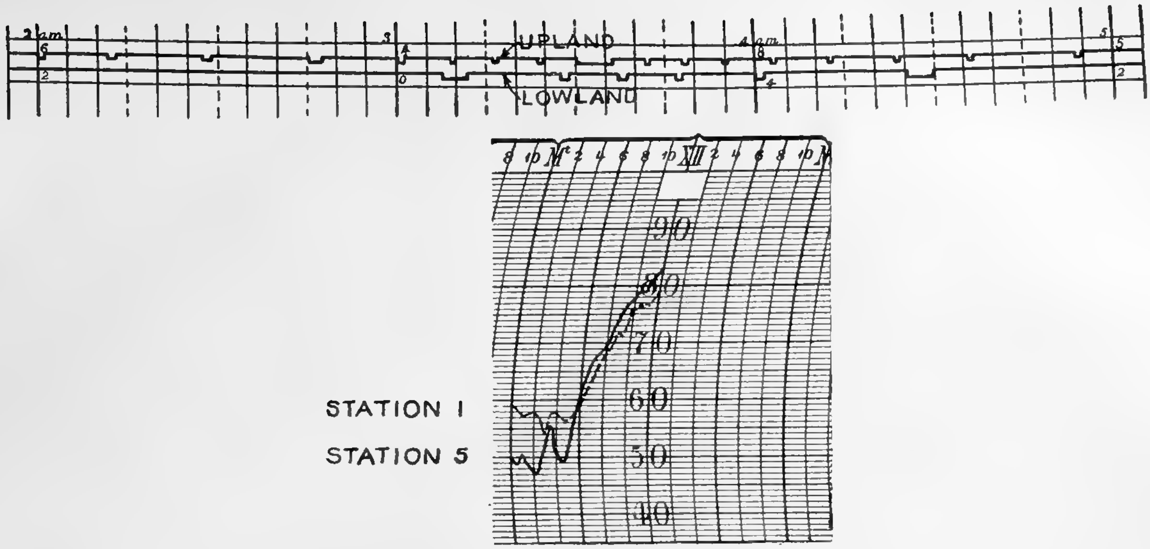

Fig. 23.—Mather, Wis.
Thermograph and anemometer records on July 27, 1906, illustrating marked effect of wind on temperature on bog as compared with that on upland.

While at night the effect of the wind on the temperature is often apparent, it is even more pronounced when some clouds at the same time pass over the moorland. Passing clouds arrest the fall in temperature, and sometimes even cause the temperature to rise. A breeze, of course, usually attends the movement of clouds over a bog. Thermograph traces showing these irregularities are quite interesting. Such a condition is illustrated by Figure 24, noon to noon, August 30–September 1, 1906, Berlin, Wis., showing the trace of a thermograph located on the bog.

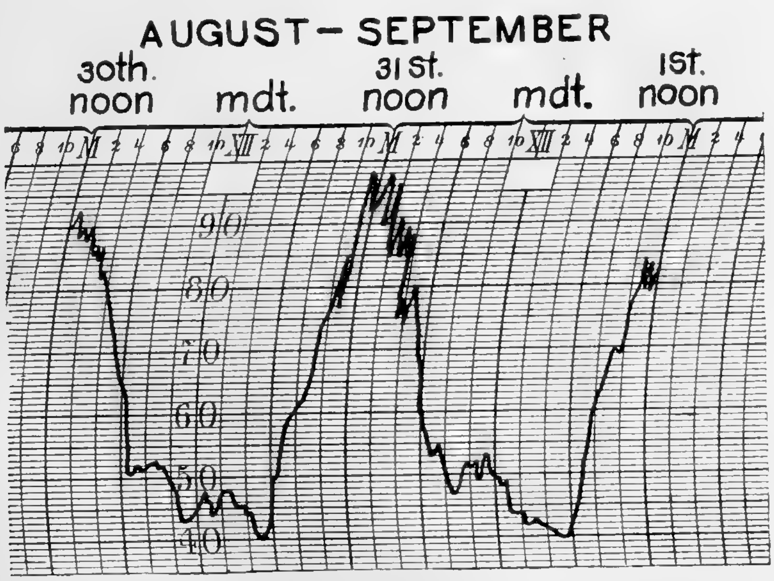

Fig. 24.—Berlin, Wis.
Thermograph record in the marsh. From noon, September 30, to noon, October 1, 1906. The trace shows the effect of passing clouds upon the temperature, both day and night.

Ordinarily a breeze does not cause such a change in temperature on the upland as on the moorland. As the cold air settles over the moorland close to the surface on clear, cool nights, a slight freshening of the wind brings warmer air from above, raising the temperature near the surface. This effect, however, can not always be noticed on the upland. The fall in temperature in the shelter on the upland may be steady through the night until the coldest point has been reached, while at the same time the thermograph trace of the instrument placed on the bog may show considerable irregularity. Such a condition was noted during the night of September 4–5, 1906, Berlin, Wis., when the wind during the evening up till 11 o'clock was "puffy." (Fig. 25.)

Exposed minimum thermometers over peat and sanded bogs at the surface, and at elevations of 5 inches and 36 inches, Berlin, Wis.—Because the locations of Stations 2 and 9 at Mather were unlike, not only as regards the character of the soil and its covering, but also as regards elevation, the exposed temperatures between similar heights above the ground are not comparable. If both stations had been located on the bog, a true comparison might be made between the temperatures of the two stations at several elevations. In the case of Stations 2 and 9 the difference in elevation is probably as important a factor as the difference in the character of the soil.

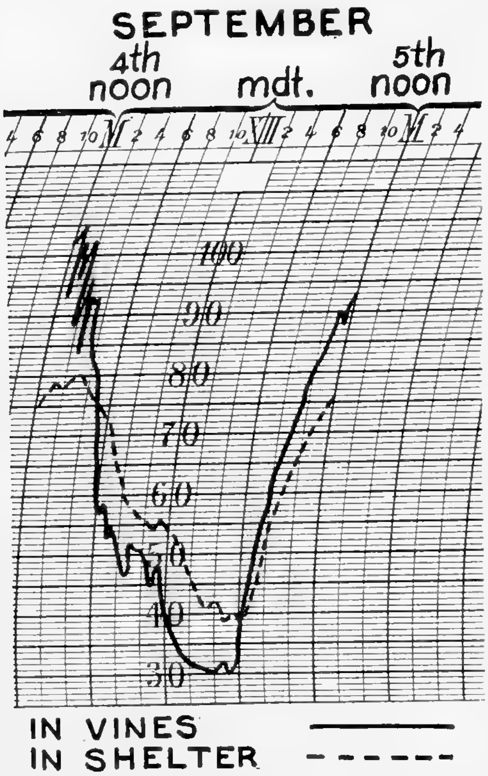

FIG. 25.—Berlin, Wis.

Traces of thermograph in shelter on upland and in vines on marsh, noon, September 4 to noon, September 5, 1906. Uncorrected readings. The trace of instrument exposed in the vines is irregular, caused by variation in wind movement.

In order to supplement Tables 13 and 14, Table 16 has been prepared from daily minimum readings made at Berlin, Wis., during September, 1906, from instruments exposed at the surface, 5 inches and 36 inches above the surface, at Stations 2 and 3, peat and sanded bogs, respectively, about 100 feet apart and on the same level. Both locations were comparatively clean, the portion of the bog in which they were located having been weeded in the spring of that year. On account of the clean surfaces the temperatures were naturally much higher than where the vegetation was dense. Another station, 5, that was maintained at Berlin, and to which reference has been made, was much colder than Station 2, but a thermometer at an elevation of 36 inches was not included in the equipment of that station. The temperature at both Stations 2 and 3 averaged lowest at the 5-inch height, 47° and 48.6°, respectively. The temperature was highest at the surface, 50.6° and 53.6°, while at the height of 36 inches there were intermediate values, 48.7° and 49°, respectively. The temperature each day was almost invariably lowest at both locations at the 5-inch height, as has been previously shown, and likewise almost invariably highest at the surface.

While in the sanded bog the surface thermometer registered on an average 5° higher than the one at 5 inches, in the peat bog the difference was 3.6°. Moreover, the surface thermometer in the sanded bog registered 4.6° higher than the one at 36 inches, while in the peat bog the difference between the thermometers similarly placed was but 1.9°. At both locations it was warmer at the surface than at the elevation of even 36 inches. This would naturally be expected over the sanded surface. As stated above, the peat soil at Station 2 was comparatively warm, that portion of the bog having been thoroughly weeded at the beginning of the season. The peat was, of course, colder than the sanded section, and it was for this reason that at Station 2 the difference between the readings at 36 inches and the surface was less than at Station 3 in the sanded section.

For similar positions at Stations 2 and 3 the average difference was greatest between the surface thermometers, 3°; at the 5-inch height the average difference was 1.6°, while at the height of 36 inches the average difference was only 0.3°. Large differences usually prevailed at the surface, while at 36 inches there was but a single instance of a difference of 1.5° or more, that being 1.6° on September 30, when the temperature was comparatively low. Sometimes the temperature over the peat at the greater elevation was slightly higher than over the sanded surface, and occasionally on days when the difference between the readings of the surface thermometers were marked, as on September 1, 3, 4, and 14, there was but very little difference at the height of 36 inches. These differences in minimum temperature should be considered as entirely due to differences in the character of the soil, as the vegetation and moisture at the stations were practically the same.

The surface of the peat at Station 3 was sanded, especially for the work of this investigation; *and while the sand served to raise the night minimums at the surface and a few inches above, it is apparent that its influence was practically lost at an elevation of 3 feet.* Ordinarily it should be expected that the differences between the thermometers at two stations at the same heights would decrease with increase of elevation, but this fact can not be demonstrated unless the stations are comparatively close together and all conditions favorable. At Mather, where the stations were far apart, the problem was more complicated.

TABLE 16.—MINIMUM TEMPERATURES IN OPEN AT SURFACE, 5 INCHES ABOVE AND 3 FEET ABOVE THE SURFACE, AT STATIONS 2 AND 3, OVER PEAT AND SAND, RESPECTIVELY, TOGETHER WITH DIFFERENCES BETWEEN THE READINGS, BERLIN, WIS., SEPTEMBER, 1906.

Day of month.	Station 2.			Station 3.			Differences.				Differences between Stations 2 and 3.		
	Surface.	5 inches.	3 feet.	Surface.	5 inches.	3 feet.	Station 2—surface and 5 inches.	Station 2—surface and 3 feet.	Station 3—surface and 5 inches.	Station 3—surface and 3 feet.	Surface.	5 inches.	3 feet.
	°	°	°	°	°	°	°	°	°	°	°	°	°
1	44.2	41.6	45.5	51.5	45.5	45.8	−2.6	+1.3	−6.0	−5.7	−7.3	−3.9	−0.3
2	58.4	59.3	59.0	58.2	59.0	59.2	*+0.9*	+0.6	*+0.8*	*+1.0*	+0.2	*+0.3*	−0.2
3	44.9	39.5	43.2	52.0	43.5	43.5	−5.4	−1.7	−8.5	−8.5	−7.1	*−4.0*	−0.3
4	43.0	38.9	41.0	51.0	41.5	41.9	−4.1	−2.0	*−9.5*	−9.1	−8.0	−2.6	−0.9
5	38.4	33.1	34.8	45.0	35.9	35.9	−5.3	−3.6	−9.1	−9.1	−6.6	−2.8	−1.1
6	46.2	40.8	42.0	52.0	42.9	42.5	−5.4	−4.2	−9.1	−9.5	−5.8	−2.1	−0.5
7	50.8	47.6	51.2	55.0	50.0	51.0	−3.2	+0.4	−5.0	−4.0	−4.2	−2.4	+0.2
8	53.6	50.0	52.4	56.8	52.7	52.3	−3.6	−1.2	−4.1	−4.5	−3.2	−2.7	+0.1
9	57.2	52.4	54.5	59.2	54.9	54.6	−4.8	−2.7	−4.3	−4.6	−2.0	−2.5	−0.1
10	62.0	57.4	59.4	64.5	60.0	60.0	−4.6	−2.6	−4.5	−4.5	−2.5	−2.6	−0.6
11	*65.1*	*64.0*	*65.2*	*66.0*	*64.6*	*65.6*	−1.1	+0.1	−1.4	−0.4	−0.9	−0.6	−0.4
12	62.1	57.4	59.0	63.9	59.5	59.6	−4.7	−3.1	−4.4	−4.3	−1.8	−2.1	−0.6
13	54.6	53.0	53.2	53.9	52.8	52.9	−1.6	−1.4	−1.1	−1.0	+0.7	+0.2	+0.3
14	35.6	33.0	34.7	43.9	35.0	35.1	−2.6	−0.9	−8.9	−8.8	*−8.3*	−2.0	−0.4
15	45.5	44.5	46.6	48.1	44.7	46.9	−1.0	+1.1	−3.4	−1.2	−2.6	−0.2	−0.3
16	56.4	54.9	56.1	56.0	55.4	56.0	−1.5	−0.3	−0.6	0.0	+0.4	−0.5	+0.1
17	59.6	57.3	58.5	62.3	59.0	58.4	−2.3	−1.1	−3.3	−3.9	−2.7	−1.7	+0.1
18	61.6	57.6	60.0	64.0	60.0	60.5	−4.0	−1.6	−4.0	−3.5	−2.4	−2.4	−0.5
19	59.6	58.0	58.6	60.0	58.1	58.4	−1.6	−1.0	−1.9	−1.6	−0.4	−0.1	+0.2
20	58.9	58.0	57.8	60.0	58.0	58.7	−0.9	−1.1	−2.0	−1.3	−1.1	0.0	−0.9
21	57.6	51.4	55.0	60.0	54.3	55.3	−6.2	−2.6	−5.7	−4.7	−2.4	−2.9	−0.3
22	54.0	47.0	48.5	55.1	48.5	48.3	−7.0	−5.5	−6.6	−6.8	−1.1	−1.5	+0.2
23	48.5	43.8	45.5	50.4	45.0	45.6	−4.7	−3.0	−5.4	−4.8	−1.9	−1.2	−0.1
24	35.7	32.5	33.4	41.0	34.0	33.5	−3.2	−2.3	−7.0	−7.5	−5.3	−1.5	−0.1
25	47.6	38.7	40.6	45.0	40.0	40.8	*−8.9*	*−7.0*	−5.0	−4.2	*+2.6*	−1.3	−0.2
26	53.3	52.8	55.1	54.8	53.4	55.1	−0.5	*+1.8*	−1.4	+0.3	−1.5	−0.6	0.0
27	*33.9*	31.0	*30.4*	40.3	*30.8*	*30.3*	−2.9	−3.5	*−9.5*	*−10.0*	−6.4	+0.2	+0.1
28	39.8	31.9	35.7	43.0	35.7	36.1	−7.9	−4.1	−7.3	−6.9	−3.2	−3.8	−0.4
29	54.8	53.6	53.5	54.3	53.5	53.0	−1.2	−1.3	−0.8	−1.3	+0.5	+0.1	*+0.5*
30	34.0	*28.8*	31.4	*39.6*	31.0	33.0	−5.2	−2.6	−8.6	−6.6	−5.6	−2.2	*−1.6*
Means	50.6	47.0	48.7	53.6	48.6	49.0	−3.6	−1.9	−5.0	−4.6	−3.0	−1.6	−0.3

Highest and lowest readings are in italics.

Maximum and minimum temperatures at different elevations, Station 9, Mather, Wis.—It having been shown in the discussion of Table 3 that the readings of the exposed maximums and minimums located at the surface varied with increasing and decreasing vegetation, it seemed advisable to show the changes in maximum as well as minimum temperature at a single station at different elevations above the surface. Table 17 contains a summary of the maximum temperature readings at Station 9 on the upland from May to September, inclusive, 1907, at the surface, 5 inches and 36 inches above the surface. The exposed minimums at these elevations are also given and are the same readings that appear in Table 14. The minimum readings, however, in this particular case are not of much importance.

There was a steady fall in maximum temperature, with increasing elevation for all the months, it being much higher at the surface than at the elevation of 36 inches. The average maximum for the season at the surface was 84.1°; at 5 inches, 79.8°; and at 36 inches, 76.2°. The greatest differences occurred in June and July. On several days the difference exceeded 15°, the greatest difference between the surface and 36 inches being 18.6° on July 20, when the surface reading was 109.3°, and that at 36 inches 90.7°. While these readings do not represent the air temperature any more than the exposed minimums do, they indicate approximately the degree of heat which affects the vegetation at different elevations. The changes, as a rule, are more abrupt between the surface and 5 inches than between 5 inches and 36 inches. The exposed maximums at the surface registered higher on an average because the surface of any solid upon which the sun shines becomes hotter than the air above, the air being heated slightly by radiation and conduction, and largely by convection. All the time while the sun is shining the air resting upon the surface is warmer than the air above, the exposed maximums naturally registering lower with increasing elevation. On cloudy days there was but little difference between the readings of the various thermometers. (For state of weather see Table 22.) The range between the exposed maximum and minimum temperatures was almost always greater at the surface than at the other positions, this difference also decreasing with increase of elevation.

TABLE 17.—MONTHLY AND SEASONAL MEANS OF MAXIMUM AND MINIMUM TEMPERATURES IN THE OPEN AT DIFFERENT ELEVATIONS, STATION 9, MATHER, WIS., 1907.

	May.[a]	June.	July.	Aug.	Sept.	Means.
Surface:	°	°	°	°	°	°
Maximum	69.2	89.4	93.7	87.4	80.8	84.1
Minimum	40.0	48.7	55.0	52.6	45.6	48.4
Range	29.2	40.7	38.7	34.8	35.2	35.7
5 inches:						
Maximum	65.8	84.4	88.5	84.3	75.9	79.8
Minimum	39.4	46.7	53.8	51.9	45.3	47.4
Range	26.4	37.7	34.7	32.4	30.6	32.4
36 inches:						
Maximum	63.3	80.7	84.1	80.3	72.6	76.2
Minimum	40.1	47.1	54.1	52.1	45.3	47.7
Range	23.2	33.6	30.0	28.2	27.3	28.5

[a] Means for nineteen days.

Average minimum temperatures for the season of 1907 for all locations, together with soil temperatures, Mather, Wis.—Table 18, giving the average minimum temperature for all exposures on the marsh at Mather for the season of 1907, together with the average departure from the minimum temperature in the shelter at Station 1, will supplement data already given. There may, at times, seem to be a discrepancy between the averages in some of the tables. On this account the footnotes should in every case be carefully read. Records of some instruments are available for the entire season at Mather from May 1, but in most instances the

record began on May 12. There were, however, interruptions at some stations on May 27 and 28, on account of reflowing the bog in anticipation of frost. Reflowing also affected the readings at other times during the season.

The principal feature of interest in Table 18 will be found in the monthly and seasonal departures of the various readings from those in the shelter at Station 1. We can see here at a glance the points of lowest and highest temperature, assuming, of course, that the temperature in the shelter of Station 1 is the standard. Of the minimums in shelters, those at Stations 2 and 5 were the lowest, averaging lower than Station 1 by 3.4° and 3.1°, respectively. The next lowest, as should be expected, was at Station 7, the average difference being 2.4°. This station was in the scalped piece, in the midst of an extensive field of sphagnum moss. The average differences for the remaining stations were as follows: Station 6, old sanded and heavily vined, 1.9°; Station 4, newly sanded and heavily vined, 1°; Station 9, sandy loam on the upland, 0.6°; and Station 3, newly sanded and thinly vined, 0.5°. The influence of sanding, draining, and cultivating is well illustrated by these figures. There is usually an interesting relation between these average shelter readings, on one hand, and the maximum soil temperature and the range in soil temperature at the 3-inch depth on the other. Station 7 is the only important exception, and this is because, although the soil temperature was relatively high in this small bare section, the air temperature was affected by the surrounding field of sphagnum moss.

The average shelter reading at Station 9 on the upland was 0.1° lower than that at Station 3, the warmest place on the bog, and the thermometers exposed in the open at the surface at both these stations averaged also within 0.1° of each other, the one at Station 9 being 0.1° higher than the one at Station 3. As has been stated before, the coldest point on the bog was at an elevation of 5 inches at Station 5, where the average was 6.7° below that in the shelter at Station 1, while the thermometer at 5 inches at Station 2 averaged 6.6° below. The greatest average monthly departure was also at the 5-inch height at Station 5, where the radiation was freer than at the surface, the October minimum averaging 8.3° lower than the one in the shelter at Station 1, and an extreme difference of 14.6° was recorded on October 24. The greatest differences between the exposed minimums and the minimum in the shelter at Station 1 as a rule occured in October, when radiation was greatest, because of the long, cool nights.

The seasonal averages of 40.2° and 40.1° at Stations 2 and 5, respectively, are so close that either might be selected as the coldest point. Sometimes in this bulletin the one at Station 2 has been used, and at other times the one at Station 5, according as the one or the other better answered the purpose. Station 2, over sphagnum moss, was located outside the cranberry marsh proper, and was ordinarily not affected by reflowing of the marsh; while Station 5 was in the cranberry bog, but in an uncultivated section, representing the average conditions prevailing in an old bog, without improvement in the way of draining, sanding, and cultivating, just as Station 3 shows approximately the best results prevalent in the Wisconsin bogs. Here, then, are wide differences between the readings of 34 different thermometers in various portions of the bog and a neighboring "island." There are, of course, reasons for these variations, the readings being affected by the character of the soil and vegetation surrounding each instrument, and often by the height of the instrument above the soil.

As previously stated, while sanding, up to a certain point, is of highest importance in preventing low night temperatures, the character of the soil is of little consequence after frost has entered it. This is evident because the differences between the minimum temperatures are not nearly so great in the month of October as in the warmer months. The temperatures over the sanded surfaces, as compared with the shelter readings at Station 1, are by far the lowest in October. At Station 3, for instance, the average departure at the surface for October was 4.5°, while the average for the entire season was but 1.3°, and in the month of July the average was but 0.1°. At Station 4 the minimum thermometer similarly located averaged 5.7° lower than the shelter at Station 1 for October, while the average departure for the season was but 3.7°. These facts are in strong contrast with the conditions prevailing at Station 5,

over peat and moss, where the minimum thermometer at the surface in October averaged 5.3° lower than in the shelter at Station 1, which was only 0.2° greater than the average departure for the entire season, 5.1°. The greatest monthly departure at Station 5 was 5.8° in July, at the time it was least at Station 3. Although the temperature at the surface at Station 3 in October was relatively low, it was, nevertheless, not as low as at the other stations in the bog. This may or may not show that the sanded surface, after frost has entered it, has greater power for warding off lower temperature than the peat and moss soil. It may be that after frost enters the soil the capacity for heat does not vary with the character of the soil, and that rather the difference in minimum temperature over two such surfaces depends then upon the character of the vegetation, and that in this instance in October the surface thermometer at Station 3 averaged higher than the surface at Station 5 only because Station 3 was thinly vined as compared with the relatively dense vegetation at Station 5.

As explained in previous paragraphs of this bulletin, the temperature at and near the surface of the bog is governed largely by the character of the soil and its covering. That this is true may be shown by a comparison of the minimum temperature readings with the soil temperature readings, especially at the depth of 3 inches. Table 19 gives the average monthly and the seasonal readings of soil thermometers placed at depths of 3 and 6 inches at the various stations. This table is the summary of extensive data which, for lack of space, it was found impracticable to print. By comparing Tables 18 and 19 it will be found that the exposed minimum temperatures at the surface at the various stations, as a rule, averaged highest where the 6 p. m. or maximum soil temperatures at the 3-inch depth were the greatest, and also where the range in soil temperature at the 3-inch depth was the greatest. Station 7 in the scalped piece is an exception to this rule, for reasons already given. In other words, the highest minimums occurred at places where the soil was heated considerably in the daytime, while at places where the soil temperature varied little on account of dense vegetation and lack of sanding and draining, the exposed minimum thermometers registered the lowest. The range in soil temperature at the 3-inch depth was naturally much greater than at the depth of 6 inches, and where the covering was exceptionally dense there was practically no range in soil temperature at the latter depth, as at Stations 2 and 5. It is evident, by referring to Figures 20 and 22, and to the soil temperature figures at the 3-inch and 6-inch depths in Table 19, that the clean soil during the daytime is not only heated considerably near the surface in the thinly vined and bare sections, but also that the heat descends to a greater depth, and it is because of this heat stored in the ground that the air above does not become as cold at night. The greater conduction of heat by the sanded soil at Station 3 and the sandy loam at Station 9 than by the plain peat at Station 7 is partially shown by the soil temperature readings at these stations, although a considerable portion of the heat received at Station 7 was expended in the evaporation of the superfluous moisture. The average daily ranges at Station 7 at the depths of 3 and 6 inches were, respectively, 5.1° and 1.4°, while at Stations 3 and 9 the ranges were, respectively, 8.2° and 4°, and 10.1° and 7.7°.

TABLE 18.—MONTHLY AND SEASONAL MEANS OF ALL MINIMUM THERMOMETERS, WITH DEPARTURES FROM MEAN OF STATION 1, MATHER, WIS., 1907.

	May.[a]		June.		July.		August.		September.		October.		Seasonal mean.	Seasonal departure.
	Monthly mean.	Monthly departure.	Monthly mean.	Monthly departure.	Monthly mean.	Monthly departure.	Monthly mean.	Monthly departure.	Monthly mean.	Monthly departure.	Monthly mean.	Monthly departure		
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
Station 1:														
Shelter	41.7	....	49.0	....	55.6	....	53.9	....	47.1	....	33.3	....	46.8	....
Station 2 (moss over peat):														
Shelter	38.9	−2.8	45.4	−3.6	51.8	−3.8	50.1	−3.8	44.3	−2.8	30.0	−3.3	43.4	−3.4
Surface	37.6	−4.1	43.3	−5.7	52.0	−3.6	49.4	−4.5	41.9	−5.2	27.5	−5.8	41.9	−4.9
2½ inches	*37.0*	*−4.7*	42.2	−6.8	49.2	−6.4	47.4	−6.5	40.8	−6.3	26.0	−7.3	40.4	−6.4
5 inches	37.2	−4.5	42.3	−6.7	49.2	−6.4	*47.1*	*−6.8*	*40.4*	*−6.7*	25.2	−8.1	40.2	−6.6
7½ inches	37.4	−4.3	42.5	−6.5	49.2	−6.4	47.5	−6.4	41.3	−5.8	26.5	−6.8	40.7	−6.1
10 inches	37.7	−4.0	42.7	−6.3	49.4	−6.2	47.3	−6.6	41.4	−5.7	26.8	−6.5	40.9	−5.9
12 inches	*37.0*	*−4.7*	42.7	−6.3	49.6	−6.0	47.5	−6.4	41.7	−5.4	27.1	−6.2	40.9	−5.9
15 inches	37.3	−4.4	43.5	−5.5	50.1	−5.5	47.8	−6.1	41.8	−5.3	27.0	−6.3	41.2	−5.6
36 inches	39.2	−2.5	45.4	−3.6	52.1	−3.5	50.4	−3.5	43.8	−3.3	28.9	−4.4	43.3	−3.5
Station 3 (newly sanded, thinly vined):														
Shelter	*41.4*	*−0.3*	*48.9*	*−0.1*	*55.6*	*0.0*	*53.8*	*−0.1*	*46.7*	*−0.4*	31.6	−1.7	*46.3*	*−0.5*
Surface	40.4	−1.3	48.8	−0.2	55.5	−0.1	53.7	−0.2	45.9	−1.2	28.8	−4.5	45.5	−1.3
5 inches	39.3	−2.4	46.3	−2.7	53.0	−2.6	51.2	−2.7	44.6	−2.5	28.5	−4.8	43.8	−3.0
36 inches	39.2	−2.5	45.9	−3.1	51.7	−3.9	48.3	−5.6	42.7	−4.4	29.2	−4.1	42.8	−4.0
Station 4 (newly sanded, heavily vined):														
Shelter	41.2	−0.5	48.4	−0.6	54.9	−0.7	53.1	−0.8	46.3	−0.8	31.2	−2.1	45.8	−1.0
Surface	38.4	−3.3	45.2	−4.0	52.3	−3.3	50.6	−3.3	44.2	−2.9	27.6	−5.7	43.1	−3.7
5 inches	38.8	−2.9	45.7	−3.3	52.4	−3.2	50.6	−3.3	44.1	−3.0	27.4	−5.9	43.2	−3.6
Station 5 (peat and moss, heavily vined):														
Shelter	39.7	−2.0	45.7	−3.3	53.1	−2.5	50.3	−3.6	44.1	−3.0	29.2	−4.1	43.7	−3.1
Surface	37.1	−4.6	43.5	−5.5	49.8	−5.8	48.8	−5.1	43.0	−4.1	28.0	−5.3	41.7	−5.1
5 inches	37.2	−4.5	*41.8*	*−7.2*	*48.8*	*−6.8*	*47.1*	*−6.8*	40.7	−6.4	*25.0*	*−8.3*	*40.1*	*−6.7*
Station 6 (old sanded, heavily vined):														
Shelter	40.4	−1.3	47.0	−2.0	53.8	−1.8	52.1	−1.8	45.3	−1.8	30.8	−2.5	44.9	−1.9
Surface	38.7	−3.0	44.0	−5.0	50.3	−5.3	49.3	−4.6	43.1	−4.0	28.3	−5.0	42.3	−4.5
5 inches	38.0	−3.7	43.2	−5.8	49.6	−6.0	48.3	−5.6	41.7	−5.4	26.1	−7.2	41.2	−5.6
Station 7 (scalped peat):														
Shelter	39.9	−1.8	46.3	−2.7	53.0	−2.6	51.6	−2.3	45.0	−2.1	30.8	−2.5	44.4	−2.4
Surface	37.6	−4.1	44.0	−5.0	51.2	−4.4	49.2	−4.7	42.3	−4.8	27.9	−5.4	42.0	−4.8
5 inches	37.6	−4.1	43.0	−6.0	50.2	−5.4	49.0	−4.9	42.6	−4.5	27.7	−5.6	41.7	−5.1
Station 9 (sandy loam):														
Shelter	41.2	−0.5	48.4	−0.6	55.4	−0.2	53.4	−0.5	46.5	−0.8	*32.3*	*−1.0*	46.2	−0.6
Surface	40.9	−0.8	48.7	−0.3	55.0	−0.6	52.6	−1.3	45.6	−1.5	31.1	−2.2	45.6	−1.2
2½ inches	40.1	−1.6	46.7	−2.3	53.7	−1.9	51.8	−2.1	45.2	−1.9	30.5	−2.8	44.7	−2.1
5 inches	40.1	−1.6	46.8	−2.2	53.8	−1.8	51.9	−2.0	45.3	−1.8	30.8	−2.5	44.8	−2.0
7½ inches	40.4	−1.3	46.9	−2.1	53.9	−1.7	52.0	−1.9	45.4	−1.7	31.0	−2.3	44.9	−1.9
10 inches	40.3	−1.4	46.9	−2.1	53.8	−1.8	51.9	−2.0	45.3	−1.8	31.0	−2.3	44.9	−1.9
12 inches	40.3	−1.4	46.9	−2.1	53.9	−1.7	52.1	−1.8	45.4	−1.7	31.0	−2.3	44.9	−1.9
15 inches	40.3	−1.4	46.9	−2.1	54.0	−1.6	51.8	−2.1	45.4	−1.7	31.0	−2.3	44.9	−1.9
36 inches	40.8	−0.9	47.1	−1.9	54.1	−1.5	52.1	−1.8	45.3	−1.8	31.1	−2.2	45.1	−1.7

[a] Mean for eighteen days.

Stations 1 and 9 on upland; others on bog. One thermometer in shelter at each station; others exposed in open.

Highest and lowest readings are in italics.

TABLE 19.—MONTHLY AND SEASONAL MEANS OF SOIL THERMOMETER READINGS AT 3 INCH AND 6 INCH DEPTH, MATHER, WIS., 1907.

[The 6 p. m. readings occurred the previous day, and "Difference" shows the change during the night.]

	May.[a]	June.	July.	August.	September.	October.	Means.
Station 2:							
3-inch depth—	°	°	°	°	°	°	°
6 p. m.	39.6	56.0	65.0	62.3	57.3	46.0	*54.4*
7 a. m.	37.5	53.0	62.6	61.2	56.5	45.4	*52.7*
Difference	− 2.1	− 3.0	− 2.4	− 1.1	− 0.8	− 0.6	− 1.7
6-inch depth—							
6 p. m.	34.8	52.8	63.2	62.2	58.3	48.2	*53.3*
7 a. m.	34.7	53.2	63.4	62.3	58.2	48.1	*53.3*
Difference	− 0.1	+ 0.4	+ 0.2	+ 0.1	− 0.1	− 0.1	*0.0*
Station 3:[b]							
3-inch depth—							
6 p. m.	55.8	65.8	71.8	68.6	63.2	49.6	62.6
7 a. m.	48.0	56.9	63.1	61.4	55.3	41.9	54.4
Difference	− 7.8	− 8.9	− 8.7	− 7.2	− 7.9	− 7.7	− 8.2
6-inch depth—							
6 p. m.	53.6	62.1	68.3	65.7	61.0	47.9	59.8
7 a. m.	50.0	57.5	63.7	62.1	57.1	44.4	55.8
Difference	− 3.6	− 4.6	− 4.6	− 3.6	− 3.9	− 3.5	− 4.0
Station 4:							
3-inch depth—							
6 p. m.	50.3	60.3	66.9	64.6	59.3	46.6	58.0
7 a. m.	47.5	56.5	63.2	61.5	56.5	44.0	54.9
Difference	− 2.8	− 3.8	− 3.7	− 3.1	− 2.8	− 2.6	− 3.1
6-inch depth—							
6 p. m.	47.7	57.1	64.2	62.9	58.5	46.5	56.2
7 a. m.	47.6	56.5	63.5	62.3	57.8	46.0	55.6
Difference	− 0.1	− 0.6	− 0.7	− 0.6	− 0.7	− 0.5	− 0.6
Station 5:[b]							
3-inch depth—							
6 p. m.	48.5	57.9	66.2	64.0	57.2	45.9	56.6
7 a. m.	47.5	55.6	63.6	62.1	56.5	45.5	*55.1*
Difference	− 1.0	− 2.3	− 2.6	− 1.9	− 0.7	− 0.4	*− 1.5*
6-inch depth—							
6 p. m.	47.1	54.8	63.7	62.3	56.7	46.7	55.2
7 a. m.	47.2	55.0	63.5	62.2	56.9	46.6	55.2
Difference	+ 0.1	+ 0.2	− 0.2	− 0.1	+ 0.2	− 0.1	*0.0*
Station 6:							
3-inch depth—							
6 p. m.	49.4	59.1	65.9	63.6	58.5	46.6	57.2
7 a. m.	47.3	56.3	63.4	61.4	56.3	44.6	54.9
Difference	− 2.1	− 2.8	− 2.5	− 2.2	− 2.2	− 2.0	− 2.3
6-inch depth—							
6 p. m.	46.8	56.4	63.2	62.3	58.1	47.1	55.6
7 a. m.	46.9	56.1	62.9	61.9	57.7	46.8	55.4
Difference	+ 0.1	− 0.3	− 0.3	− 0.4	− 0.4	− 0.3	− 0.2

[a] Means for seventeen days.

[b] On August 10 and 12 a light covering of moss was placed around and between soil thermometers at Station 5. On August 25, at Station 3 position of box on which soil thermograph rested was changed so as to allow more sunshine around soil thermometers during morning hours. On August 24, at Station 5 positions of soil thermographs were changed and placed under proper conditions of live moss and vines.

Station 2. Sphagnum moss.
Station 3. Newly sanded, thinly vined.
Station 4. Newly sanded, heavily vined.
Station 5. Peat with moss, heavily vined.
Station 6. Old sanded, heavily vined.

Highest and lowest readings are in italics.

TABLE 19.—MONTHLY AND SEASONAL MEANS OF SOIL THERMOMETER READINGS AT 3 INCH AND 6 INCH DEPTH, MATHER, WIS., 1907—Continued.

	May.	June.	July.	August.	September	October.	Means.
Station 7:							
3-inch depth—	°	°	°	°	°	°	°
6 p. m.	49.5	61.9	68.8	66.9	61.4	48.6	59.5
7 a. m.	45.9	56.2	63.4	62.0	55.6	43.6	54.4
Difference	− 3.6	− 5.7	− 5.4	− 4.9	− 5.8	− 5.0	− 5.1
6-inch depth—							
6 p. m.	45.1	58.7	66.1	65.1	59.3	47.1	56.9
7 a. m.	44.9	56.9	64.4	63.5	57.7	45.8	55.5
Difference	− 0.2	− 1.8	− 1.7	− 1.6	− 1.6	− 1.3	− 1.4
Station 9:							
3-inch depth—							
6 p. m.	56.8	69.1	75.2	70.9	63.5	53.0	*64.8*
7 a. m.	47.2	58.0	64.0	61.4	54.8	42.7	54.7
Difference	− 9.6	−11.1	−11.2	− 9.5	− 8.7	−10.3	*−10.1*
6-inch depth—							
6 p. m.	55.3	67.9	74.4	70.8	63.0	52.0	*63.9*
7 a. m.	48.6	58.9	65.3	62.8	56.6	44.7	*56.2*
Difference	− 6.7	− 9.0	− 9.1	− 8.0	− 6.4	− 7.3	*− 7.7*

Station 7. Scalped piece, bare peat, in a field of sphagnum moss. Station 9. Sandy loam on upland.

Highest and lowest readings are in italics.

That the range in soil temperature was much greater at Station 3 than at Station 5, and at the 3-inch depth than at the depth of 6 inches at both stations, is shown graphically by Figure 20, previously referred to, which gives the hourly traces from soil thermographs for the season of 1907 at each station. Figures 21 and 22, which have already been discussed, bear directly upon this question of air and soil temperatures. While the maximum at 3 inches occurred at both stations from 4 to 6 p. m., and the minimum from 6 to 7 a. m., the maximum and the minimum at 6 inches at Station 3 occurred a few hours later, and at the 6-inch depth at Station 5 the maximum occurred from 8 to 9 a. m. and the minimum about 5 p. m. The curve at Station 3 at the 3-inch depth is, of course, abrupt as compared with the curves at the other exposures.

Figure 19, also previously referred to, shows the curve of the soil thermograph records at Stations 3, 4, and 5 for the week of September 23–30, inclusive, 1906. The great range in temperature in the thinly vined and newly sanded section as compared with that in the peat bog with moss is apparent, while the one exposed in the heavily vined and newly sanded section has an intermediate value. The changes in soil temperature at Station 3 are again shown to be abrupt as compared with those at the other stations, the minimum being below as much as the maximum was above. Of course, the location at Station 3 was responsive to changes in air temperature, while the changes where the vegetation was dense lagged behind and were relatively slight.

A soil thermograph was located in the reservoir so as to secure a continuous record of water temperature 12 inches below the surface, while an air thermograph was placed in a shelter over the bog 5 inches above the surface. In Figure 26 are shown the curves of these two instruments, and also the curve of the soil thermograph over a peat and moss bog, for the week of September 23–30, inclusive, 1906. Here we have an interesting illustration of the daily variation in temperature in three elements—air, earth, and water—within a comparatively small area.

In Figure 27 the curves of air temperature, water temperature, and soil temperature for the week of September 16–23, inclusive, 1906, are illustrated. It is interesting to note the lagging of the changes in temperature of the soil and water behind those of the air.

Relation between dew-point and minimum temperature.—A dry atmosphere permits freer radiation of heat from the ground than moist air. Moist air absorbs part of the heat radiated from the ground, and consequently does not permit as low temperatures as when the air is dry. The marsh region of Wisconsin, however, is almost always humid at night, but remarkably low temperatures, nevertheless, occur in spite of these humid conditions. It may be that under such conditions the air some little distance above the bog is relatively dry and permits rapid radiation through it.

It has long been supposed that a relation exists between the dew-point and the ensuing minimum air temperature, and that, if the dew-point at the time of observation in the evening was higher than 32°, frost should not be expected that night. It was believed that, the dew-point having been reached, latent heat would be given off in the operation of condensation and prevent any further fall in temperature. This is a plausible theory, and many cranberry

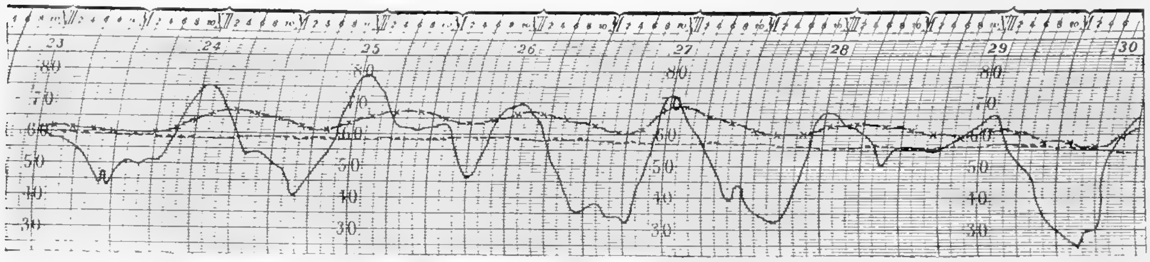

FIG. 26.—Temperature curves of air, soil and water for Mather, Wis., September 23 to 30, 1906. Air temperature in shelter over bog ——; temperature of water in reservoir 12″ below surface, —x—x—x—x—x—x—x—x; soil temperature 3″ deep in peat bog with moss ------------------.

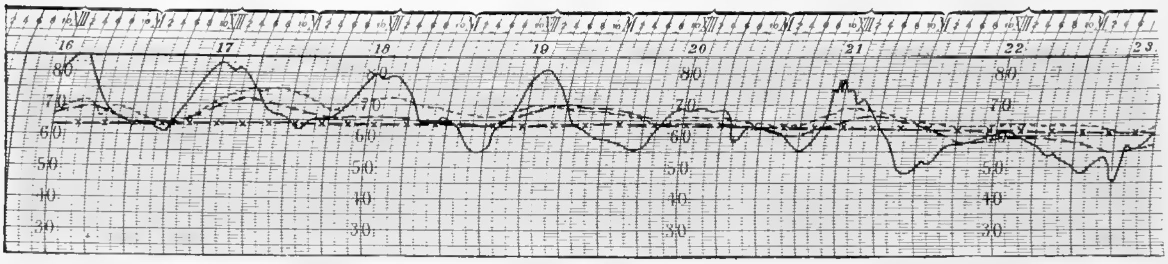

FIG. 27.—Temperature curves of air, soil and water for Stations 3 and 5, Mather, Wis., September 16 to 23, 1906. Air temperature, station 5, in shelter, ——; soil temperature, station 5, 3 in. deep, —x—x—x—x—x—x—x; soil temperature, station 3, 3 in. deep — — — — — — —; temperature of water in reservoir, 12 in. below surface ------

growers have confidence in it, but the observations made on the bogs show that the dew-point itself is no indication whatever of the ensuing minimum temperature.

The dew-point observations were made at Mather with the Assman aspiration psychrometer exposed on the upland about 4 feet above the ground at Station 1 and on the bog about 1 foot above the ground at Station 4. During the season of 1907 the dew-point on the upland was generally lower at 9 p. m. than at 6 p. m., the average difference for the season being 1.9°. (Tables 20 and 20*a*.) However, the ensuing minimum temperature in the shelter at Station 1 was almost invariably lower than the 9 p. m. dew-point reading, the average depression for the season being 3.3°.

The latest dew-point observation made daily at Station 4 was at 6 p. m. On account of the larger amount of moisture prevalent on the bog, the dew-point was naturally higher there than on the upland, there being an average difference between the 6 p. m. readings of 1.5°. The average of the dew-point readings for the season of 1907 at Station 4 was 7.6° higher than the mean of the ensuing minimum air temperatures in the shelter at the same station on the bog, as compared with an average difference of 8.2°, noted in the season of 1906. Moreover, at Station 4 the minimum in the open averaged 2.6° lower than in the shelter. (Table 1.) The

average temperature at one of the coldest points on the bog in the open—the 5-inch height at Station 2—was 13.7° below the average of the dew-point readings at Station 4 during the season of 1907. On some nights the temperature in the shelter at Station 4 was 18° to 20° lower than the dew-point. On one night, September 29–30, it was 28° lower, and this in spite of the fact that the relative humidity on the bog early the previous evening was as high as 94 per cent. The temperature in the open at Station 2 was often as much as 25° lower, and on September 30 it was 30° lower. In a few cases the ensuing minimum temperatures were higher, as for instance on June 3 and 10, July 11, August 31, and October 9 and 15, when the weather was cloudy. During cloudy weather the dew-point and the minimum temperature at Station 4 were often the same. According to these observations the formation of dew and fog has no appreciable effect in preventing the fall of the minimum temperature to a low point, such a fog often lying in a thin stratum over the marsh; in fact, the greatest departures often occurred on nights of dew and fog when the sky above was clear. Of course, latent heat is given off in the process of condensation, but the amount is obviously small as compared with the vast area of cold air overlying the moorland. Table 22 should be used in connection with Table 20 for purposes of comparison regarding fog and dew.

It is apparent then from the above that in the moorlands the dew-point in the evening is no indication of the ensuing minimum temperature. Naturally if the air were drier, the temperature would fall to a lower point, but the air is usually humid in the bogs, as stated above. The vapor in the air is so great that ordinarily on clear cool nights dew forms even at sunset. In spite of the fact that the air may be saturated with moisture, the temperature frequently continues to fall steadily through the night, demonstrating that the latent heat given off in condensation has but little effect in retarding the fall in temperature. The thermograph traces of the instruments exposed in the open often show a steady decline in temperature on nights of dew and fog when the sky is clear.

TABLE 20.—COMPARISON OF DEW-POINT READINGS ON THE UPLAND AT 6 AND 9 P. M., WITH ENSUING MINIMUM TEMPERATURES IN THE SHELTER; ALSO OF DEW-POINT READINGS ON THE MARSH AT 6 P. M., WITH ENSUING MINIMUM TEMPERATURES, AND DIFFERENCES AT STATION 4; ALSO ENSUING MINIMUM TEMPERATURES IN OPEN, AND DIFFERENCES AT STATION 2, MATHER, WIS., 1907.

[Dew-point readings occurred the previous day.]

Day of month.	June.								July.								August.							
	Upland, Station 1—shelter.			Marsh.					Upland, Station 1—shelter.			Marsh.					Upland, Station 1—shelter.			Marsh.				
	Dew-point.			Station 4—shelter.			Station 2—5 inches, exposed.		Dew-point.			Station 4—shelter.			Station 2—5 inches, exposed.		Dew-point.			Station 4—shelter.			Station 2—5 inches, exposed.	
	6 p. m.	9 p. m.	Minimum.	6 p. m. d. p.	Minimum.	Difference.	Minimum.	Difference.	6 p. m.	9 p. m.	Minimum.	6 p. m. d. p.	Minimum.	Difference.	Minimum.	Difference.	6 p. m.	9 p. m.	Minimum.	6 p. m. d. p.	Minimum.	Difference.	Minimum.	Difference.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	*34*	*33*	36	*34*	*35*	+ 1	*28*	− 6	64	62	59	62	58	− 4	52	−10	57	58	55	62	53	− 9	47	−15
2	40	41	39	43	36	− 7	29	−14	53	*50*	*38*	53	*37*	−16	29	−24	52	47	46	*49*	45	− 4	39	−10
3	46	49	55	48	55	+ 7	53	+ 5	*50*	*60*	48	*51*	47	− 4	38	−13	52	53	48	54	47	− 7	40	−14
4	52	50	41	51	42	− 9	35	−16	67	61	51	65	51	−14	45	−20	49	48	39	54	43	−11	34	−20
5	44	45	44	42	44	+ 2	38	− 4	66	65	60	66	61	− 5	59	− 7	54	61	59	56	59	+ 3	58	*+ 2*
6	36	40	*34*	39	36	− 3	*28*	−11	*70*	*68*	58	*70*	58	−12	53	−17	57	56	54	59	52	− 7	46	−13
7	45	45	48	48	48	0	45	− 3	56	54	51	60	51	− 9	43	−17	70	63	57	71	56	−15	48	−23
8	38	39	36	42	*35*	− 7	*28*	−14	69	67	59	67	55	−12	47	−20	58	57	55	62	56	− 6	51	−11
9	39	39	41	42	40	− 2	32	−10	62	63	61	63	60	− 3	51	−12	59	59	54	60	54	− 6	49	−11
10	47	43	54	46	55	*+ 9*	53	*+ 7*	57	56	50	59	50	− 9	42	−17	70	69	59	69	60	− 9	55	−14
11	60	57	47	61	46	−15	39	−22	59	60	60	59	61	*+ 2*	60	*+ 1*	*71*	*70*	*74*	*72*	*70*	− 2	*70*	− 2
12	54	50	53	54	53	− 1	50	− 4	60	60	51	60	48	−12	42	−18	56	*42*	53	57	49	− 8	40	−17
13	51	50	44	54	42	−12	34	−20	60	59	54	61	52	− 9	44	−17	56	57	50	58	49	− 9	42	−16
14	46	48	39	50	40	−10	31	−19	62	59	62	62	62	0	56	− 6	58	59	53	59	53	− 6	46	−13
15	51	53	43	60	41	*−19*	35	*−25*	69	67	*68*	68	*68*	0	68	0	64	60	56	64	56	− 8	50	−14
16	56	54	54	56	53	− 3	46	−10	64	60	51	66	52	−14	46	−20	66	64	61	66	62	− 4	58	− 8
17	*70*	*68*	*70*	*70*	*69*	− 1	*63*	− 7	*70*	67	57	*70*	52	*−18*	45	*−25*	60	52	52	54	50	− 4	43	−11
18	64	65	59	67	57	−10	50	−17	56	59	50	63	50	−13	44	−19	60	60	57	59	54	− 5	48	−11
19	64	56	57	64	56	− 8	47	−17	62	62	56	64	57	− 7	52	−12	67	66	65	68	65	− 3	65	− 3
20	56	55	51	61	50	−11	42	−19	67	65	61	66	59	− 7	50	−16	54	51	*43*	52	42	−10	34	−18
21	58	55	49	60	49	−11	41	−19	62	67	64	69	65	− 4	60	− 9	*47*	43	47	*49*	48	− 1	36	−13
22	64	62	61	64	62	− 2	59	− 5	68	66	64	68	63	− 5	57	−11	53	50	*43*	53	*41*	−12	34	−19
23	67	65	60	67	60	− 7	54	−13	61	59	53	63	52	−11	49	−14	56	53	54	55	54	− 1	47	− 8
24	63	64	54	65	55	−10	50	−15	67	65	64	67	64	− 3	59	− 8	67	61	54	67	51	*−16*	41	*−26*
25	66	61	58	69	57	−12	53	−16	60	64	53	64	54	−10	50	−14	52	48	48	52	43	− 9	*33*	−19
26	48	52	48	51	48	− 3	41	−10	64	62	49	65	48	−17	42	−23	52	49	51	58	50	− 8	42	−16
27	49	53	45	54	43	−11	35	−19	68	*50*	45	60	46	−14	41	−19	57	55	56	56	56	0	56	0
28	56	54	43	61	44	−17	37	−24	59	61	59	60	59	− 1	55	− 5	63	62	58	64	56	− 8	50	−14
29	58	56	51	59	50	− 9	43	−16	59	58	57	60	56	− 4	48	−12	64	56	51	63	51	−12	44	−19
30	64	62	58	65	56	− 9	49	−16	53	53	53	56	50	− 6	45	−11	64	64	64	64	64	0	62	− 2
31	.....	.....	.....	.....	.....	.....	.....	.....	66	62	58	66	55	−11	48	−18	67	61	58	54	58	*+ 4*	52	− 2
Means	52.9	52.1	49.1	54.9	48.6	−6.3	42.3	−12.6	62.3	60.7	55.6	63.0	54.9	−8.1	49.0	−14.0	59.1	56.3	54.0	59.4	53.1	−6.3	47.1	−12.3

Highest and lowest readings are in italics.

Table 20.—Comparison of Dew-point Readings on the Upland at 6 and 9 p. m., with Ensuing Minimum Temperatures in the Shelter; also of Dew-point Readings on the Marsh at 6 p. m., with Ensuing Minimum Temperatures and Differences at Station 4; also Ensuing Minimum Temperatures in Open, and Differences at Station 2, Mather, Wis., 1907—Continued.

Day of month.	September.									October.									
	Upland, Station 1—shelter.			Marsh.						Upland, Station 1—shelter.			Marsh.						
	Dew-point.		Minimum.	Station 4—shelter.			Station 2—5 inches, exposed.			Dew-point.		Minimum.	Station 4—shelter.			Station 2—5 inches, exposed.			
	6 p. m.	9 p. m.		d. p. 6 p. m.	Minimum.	Difference.	Minimum.	Difference.		6 p. m.	9 p. m.		d. p. 6 p. m.	Minimum.	Difference.	Minimum.	Difference.		
	°	°	°	°	°	°	°	°		°	°	°	°	°	°	°	°		
1	*74*	*71*	*70*	*76*	*68*	− 8	*61*	−15		40	35	33	39	33	− 6	27	−12		
2	61	55	53	61	52	− 9	42	−19		50	*51*	*52*	52	*52*	0	*45*	− 7		
3	48	50	50	54	50	− 4	40	−14		*54*	46	46	54	43	−11	36	−18		
4	54	52	52	56	53	− 3	45	−11		*54*	*51*	41	*56*	37	−19	27	*−29*		
5	52	49	44	57	44	−13	36	−21		41	44	41	36	38	+ 2	27	− 9		
6	53	52	41	56	41	−15	33	−23		50	44	44	49	42	− 7	34	−15		
7	57	55	54	56	56	*0*	55	*− 1*		48	*51*	50	55	44	−11	37	−18		
8	58	58	56	58	56	− 2	56	− 2		44	32	23	44	22	*−22*	16	−28		
9	49	50	40	52	40	−12	30	−22		27	41	40	32	40	*+ 8*	33	+ 1		
10	49	43	38	48	42	− 6	30	−18		43	38	35	43	31	−12	25	−18		
11	51	47	45	53	45	− 8	37	−16		29	30	35	42	35	− 7	26	−16		
12	54	52	48	59	43	−16	37	−22		30	36	29	30	29	− 1	23	− 7		
13	59	57	50	61	47	−14	40	−21		31	*22*	25	32	22	−10	16	−16		
14	61	58	62	66	60	− 6	57	− 9		28	26	22	26	20	− 6	16	−10		
15	64	59	63	64	60	− 4	54	−10		38	40	44	36	44	*+ 8*	39	*+ 3*		
16	63	66	67	73	66	− 7	64	− 9		44	42	36	39	36	− 3	29	−10		
17	63	58	53	67	52	−15	44	−23		52	44	39	50	33	−17	27	−23		
18	63	62	58	63	58	− 5	56	− 7		46	24	24	36	24	−12	18	−18		
19	67	66	61	70	61	− 9	58	−12		*20*	26	27	26	22	− 4	18	− 8		
20	69	66	60	71	59	−12	57	−14		33	35	28	36	27	− 9	22	−14		
21	54	43	38	54	38	−16	30	−24		29	25	19	28	18	−10	13	−15		
22	*31*	43	31	*36*	35	− 1	23	−13		34	33	40	41	36	− 5	31	−10		
23	49	46	45	50	44	− 6	37	−13		48	27	30	45	26	−19	22	−23		
24	48	46	43	54	43	−11	40	−14		42	30	29	46	25	−21	18	−28		
25	34	*32*	*28*	40	25	−15	20	−20		29	31	28	35	25	−10	17	−18		
26	36	33	34	42	35	− 7	25	−17		23	24	19	29	18	−11	12	−17		
27	44	42	34	50	34	−16	27	−23		32	39	34	35	34	− 1	29	− 6		
28	44	40	37	46	39	− 7	35	−11		*20*	*22*	*17*	*20*	*16*	− 4	*10*	−10		
29	38	38	29	46	30	−16	25	−21		29	25	32	35	28	− 7	26	− 9		
30	46	39	*28*	49	*21*	*−28*	*19*	*−30*		40	38	37	40	37	− 3	35	− 5		
31	......	......	......	......	......	......	......	......		41	42	37	41	35	− 6	29	−12		
Means	53.1	50.9	47.1	56.3	46.6	−9.7	40.4	−15.9		37.7	35.3	33.4	39.0	31.4	−7.6	25.3	−13.7		

Highest and lowest readings are in italics.

TABLE 20a.—MONTHLY AND SEASONAL MEANS—DEW-POINT AND ENSUING MINIMUM TEMPERATURES, MATHER WIS., 1907.

	June.	July.	August.	September.	October.	Means.
Upland:						
Station 1, shelter—						
Dew-point.	°	°	°	°	°	°
6 p. m.	52.9	62.3	59.1	53.1	37.7	53.0
9 p. m.	52.1	60.7	56.3	50.9	35.3	51.1
Minimum	49.1	55.6	54.0	47.1	33.4	47.8
Marsh:						
Station 4, shelter—						
Dew-point.						
6 p. m.	54.9	63.0	59.4	56.3	39.0	54.5
Minimum	48.6	54.9	53.1	46.6	31.4	46.9
Difference	− 6.3	− 8.1	− 6.3	− 9.7	− 7.6	− 7.6
Station 2, 5 inches, exposed—						
Minimum	42.3	49.0	47.1	40.4	25.3	40.8
Difference	−12.6	−14.0	−12.3	−15.9	−13.7	−13.7

Dew-point readings at Berlin.—Observations of dew-point and the ensuing minimum air temperature made at Berlin in 1906 confirm the results obtained at Mather. Even though the air was saturated in the early evening and dew formed rapidly, the temperature often fell steadily in spite of the large amount of latent heat liberated by the condensation of water vapor into dew, as on the night of September 23–24. Of course the fall in temperature was not so rapid when the humidity was high and the dew was forming fast, but there was, nevertheless, usually a steady fall on clear nights. The moist condition simply tended to lower the rate of cooling, and it is probable that the radiation of heat from the dewdrops themselves was great. Aside from reference to the tables compiled from Mather observations, a few comparisons made at Berlin are given below between the dew-point in the evening preceding nights of frost with the ensuing minimum temperature.

	Dew-point previous evening.	Minimum temperature, shelter readings, Station 1.	Minimum temperature, 5 inches, Station 5.
	°	°	°
September 5	56	42	28
September 14	50	41	29
September 24	48	38	29
September 27	47	36	24
September 28	47	41	28
September 30	41	38	23
October 1	46	29	19
Averages	47.9	37.9	25.7

In a dry section at some little distance from water and bog land there may be some connection between the dew-point and the ensuing minimum temperature. When a high degree of moisture is present in the air as over a moorland, and when the temperature falls rapidly in the evening, as it usually does on clear nights, the point of saturation is reached in a brief period.

Fog over marshes and low temperatures.—Fog, even though light, has been supposed by some to be a preventive of frost, but this is not quite true; in fact, fog may form over a bog on almost any clear cool night following a warm day when the soil has been heated and the air for some distance above the surface highly charged with water vapor. The rapid radiation from the surface and humid air on a clear night after a warm day carries the temperature below the dew-point, and fog is immediately formed. It is often said that the formation of

fog under such conditions indicates a rapid fall in temperature, and cranberry growers are accustomed to look for a frost when on a clear night light fog forms over the moorland. On such nights the radiation of heat from the particles of fog serves even to lower the temperature of the air. Of course, the radiation of heat from the ground is more or less arrested as the fog increases, but it is surprising what little effect fog seems to have in preventing low night minimum temperatures in the bogs.

Special observations on critical nights at the Berlin marsh, September, 1906.—Personal observations in the bog at Berlin, 1906, during several nights when low temperatures occurred, convinced the writer that high humidity and even fog have hardly any effect in retarding the fall in temperature. Even when the bog seemed reeking with moisture, the temperature fell steadily. Often during critical nights, observations of special conditions were made nearly every hour in certain portions of the marsh. There was little opportunity for this kind of work until September, as the temperature during the summer was far above the normal.

On August 27 the exposed minimum temperature at Station 5, in the "ferns," at the 5-inch height was 30.5°, while near the surface at the same place the minimum was 32.2°, and in the shelter at Station 1 it was 45.5°. No frost, however, was observed that morning at any point in the bog. On the morning of September 5 the minimum temperatures were 28.3° at the 5-inch height and 32° at the surface at Station 5, and 42° in the shelter at Station 1. Again, no hoar frost was observed, although the exposed minimums registered several degrees below the freezing point. The ferns, however, were damaged by this low temperature, as they began to wither immediately afterwards, and some slight damage was noted in the neighboring lowlands outside the marsh. Occasionally light frost may occur in the bogs and pass unnoticed, disappearing very early in the morning, and the writer has known of several instances where frost was not observed, although damage to vegetation gave evidence of its occurrence. While these minimum temperatures, of course, do not represent the temperature of the air, yet, even if they represent approximately the temperature of the plants and vines, hoar frost might be expected when these readings fell a few degrees below freezing. The first date on which frost was actually observed at Berlin was September 14, under conditions quite similar to those of the 5th. The shelter minimum at Station 1 was 41.3°, while the minimums at the 5-inch height and at the surface at Station 5 were 28.8° and 32.6°, respectively. The morning of the 14th was clear, but with fog over the marsh. (Fig. 6.) Light frost was observed first on the wooden car tracks at the intersections where the rails had been spliced, but not on the main portions of the track, or on the cross-ties lower down. (Figure 17 shows the tracks and cross-ties.) These splices were about 4 inches above the surface of the marsh, and afforded a better opportunity for radiation. A peculiar phenomenon was noticed at Station 5: *The maximum and the minimum thermometers at the 5-inch height were found completely covered with frozen dewdrops, dew having been deposited sometime during the night, after which the temperature fell to the freezing point. The thermometers resting on the surface were absolutely free from frost or moisture of any kind. This is a most striking example of safety at the surface and frost and possibly destruction a few inches above.* Some frozen dewdrops were also found on the tops of the splices already referred to. Ordinarily, dew formed on vines and other objects at an elevation of a few inches above the ground sooner than at the immediate surface, doubtless because at that elevation there was no direct connection with the warm ground and the radiation was freer, the dew-point was more readily reached, rather than because of any difference in the amount of moisture. A light frost occurred at Mather and Cranmoor on September 14, as well as at Berlin, temperatures below freezing being reported in all the Wisconsin bogs. The frost on the 14th would probably have been more severe had the soil been colder; but it was comparatively warm, because of a hot wave of several days preceding the cool spell. On the 14th considerable differences prevailed between the temperatures on the uplands and in the bogs, as is usual under such conditions.

Light frost was again observed at Berlin on September 24, freezing temperatures being recorded at both exposures at Station 5, but the temperatures were not so low at Cranmoor

and Mather, the sky there becoming overcast before midnight. The Berlin marsh was quite wet from recent rains, especially in the east portion where the water was almost up to the surface. The water had been partially drained from the west portion, but it was still wet, especially on low ground. In the big ditch near Stations 2, 3, and 4, the water was but 2 to 3 inches below the surface. The sky was clear during the entire night. About 7 p. m. on the 23d fog was first observed along the main ditch; after midnight the fog increased and spread over the bog, and by 3 a. m. it was very dense. The whole marsh seemed to be reeking with moisture. The relative humidity was 100 per cent continuously after 10 p. m., yet the temperature fell rather uniformly until 4 a. m.; then after remaining stationary about an hour it rose gradually. In the morning frost was observed on most of the wooden car tracks, especially where they were situated away from the water. None was observed on the cross-ties resting on the surface of the bog, and while frost was seen generally on the tracks, it was more pronounced on the edges and on the upper side of the splices covering the joints of the rails, where radiation was freest. In other words, frost was heavier at a slight elevation on account of freer radiation than at the immediate surface, this being consistent with the readings of the thermometers. The minimum temperature on top of the tracks was 27°. A thermometer placed in the vines, a few inches above the surface and just touching three berries, registered a minimum of 31°. The instrument and the exposed berries were covered with frost, but the berries near the ground were not frosted. Frost was also observed on the leaves, vines, and grasses, but no damage as a result was afterwards noticed. A thermograph placed in the "ferns" where the vegetation had been trampled was covered with frost and registered a minimum of 26°. Invariably lower minimums were found in sections that had been trampled than in the unpicked sections where the vines and grasses stood upright.

Frost occurred in all marshes on September 27 and 28, it being heavy at Berlin on the 27th and light on the 28th, increasing cloudiness after midnight of the 27th preventing the frost from becoming severe. Dew did not form rapidly on the first night. At 10 p. m. the shelter thermometer at Station 1 registered 50° and the dew-point was 46°. The marsh was comparatively dry, in strong contrast with the moist conditions of a few days previous. The shelter thermometer at Station 1 fell from 50° to 45° between 10.30 p. m. and 11 p. m., but there was no sign of frost at the latter hour; the tracks were dry and the dew-point was 43°. Some fog appeared about midnight, the temperature continued to fall steadily, and frost was observed first on the metallic covering of the thermograph in the "ferns" at 1 a. m., where the temperature had fallen to 28°. A few minutes later it was observed on the splices of the car tracks near by, and by 2 a. m. on the entire track. At that time the temperature on top of the track was 27° and on the cross-ties 31.5°. At 4 a. m. these readings were 24° and 30°, respectively. A thermometer placed in the midst of berries about 5 inches above the surface recorded 28°, and another about an inch above the surface, 29°. The thermometer at the 5-inch height in the "ferns" at Station 5 on the morning of the 27th registered a minimum of 24.4°. Frost was again most noticeable on the marsh where the vines had been trampled and hardly noticeable where they stood upright. Although the berries were covered with frost, it had evidently not penetrated the skin, and no resulting damage was apparent later. The frost on the 28th was light in the various sections.

The most important frosts of the autumn season of 1906 occurred on September 30 and October 1. The barometer was high in the marsh region on these two nights, as on previous occasions when low temperatures occurred. The weather maps showing the distribution of pressure will be discussed later. At Berlin, on the 29th, the temperature did not fall rapidly until late in the evening, as the sky was covered with clouds, which did not disappear until after 10 p. m. The temperature then fell rapidly, reaching a minimum of 23.2° in the "ferns" at Station 5 on the marsh. *Heavy frost was general over the entire bog, but the berries were apparently not frozen, and no resulting damage was noticed, although flowing was not resorted to.*[a]

[a] The berry when green can usually withstand a temperature in "the open" of about 28°, and when fully matured, of 23° or 24°, depending, of course, upon the duration of the critical temperature.

On the morning of October 1 the most severe frost of the season occurred, the temperature in the "ferns" at the surface being 23° and at the 5-inch height 19°. On the wooden cross-ties of the track the minimum was 18°, and 4 inches lower at the surface it was 22°. A thermometer placed in the midst of a bunch of berries about 5 inches above the surface registered 22°, and another instrument 1 inch above the surface, between the berries, registered 24°. The shelter minimum at Station 1 was 29.4°, while a thermometer on a board walk on hard land near Station 1, where heavy frost occurred, registered 22.8°. The temperature of the water in the reservoir at daybreak was 53°, and in two small ditches it was 37° and 39°. All the berries remaining unpicked were frozen hard as marbles, with the exception of those near the surface of the dry sanded section where the minimum temperature was 35.8°. As the berries thawed out, however, only about 33 per cent of them showed injury. In other words, about one in three was soft and semi-transparent, and the other two were firm and apparently in good condition. The berries that were exposed directly to the sun's rays in the morning thawed out rapidly and showed the effects of the frost, there being an unusually rapid rise in temperature on the morning of October 1. (Figure 28 shows the thermograph traces in shelter and on the marsh.) The majority of the berries were located below the thick growth of vines and other vegetation, so that the sun's rays did not directly strike them and warm them rapidly, and the thawing was, as a result, gradual. If the morning of October 1 had been cloudy, permitting the slow thawing out of the uppermost berries, it is possible that the entire crop might have escaped serious injury. Other fruits as well, after having been frozen, fail to show the effects of frost when the thawing is gradual.

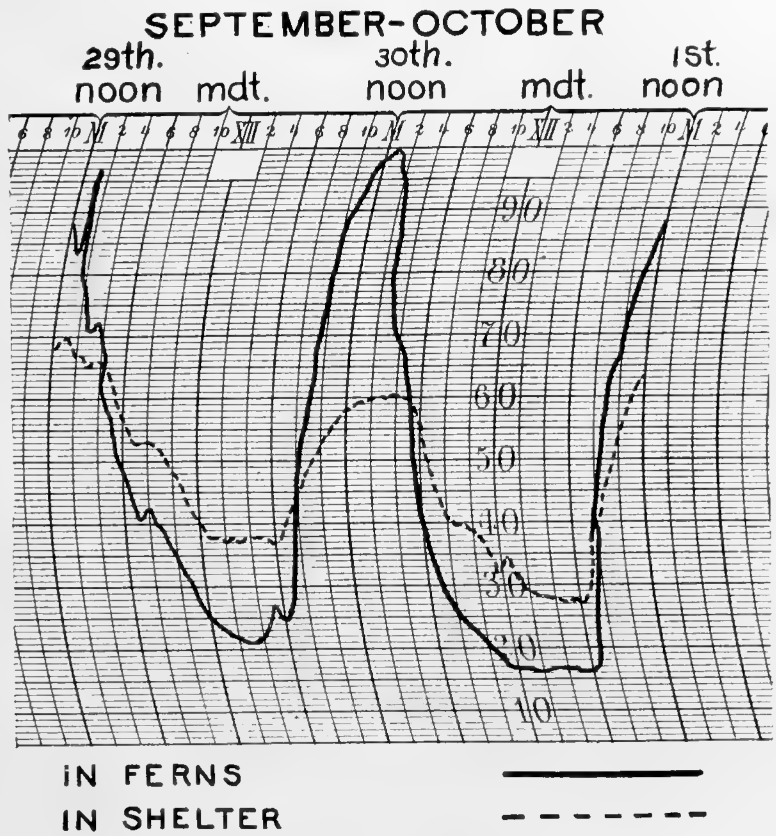

FIG. 28.—Berlin, Wis.
Temperature curves in shelter Station 1, and in open in the ferns Station 5, noon September 29 to noon October 1, 1906. Uncorrected readings.

Effect of frost on the cranberry.—The resisting power of the cranberry increases steadily as it matures. In the autumn, when colored and fully matured, the berry can withstand a temperature many degrees lower than when green and unripe. As it ripens it not only colors but the skin thickens, and its content changes somewhat and offers an increased resistance to frost. Growers state that sometimes, although no damage is apparent after freezing weather, the berry thus exposed is chilled, and if placed near a fire will become semi-transparent and soft, resembling somewhat a baked apple, and show all the characteristics of having been frozen. An experiment was made on the morning of September 30 by placing some of the chilled berries near a fire, but no deterioration was detected in any of them. It is said that berries exposed to frost on two successive nights, after apparently having escaped injury the first night, will on the morning following the second night exhibit symptoms of being frozen, even though the cold on the second night is not as severe as on the first. It is supposed that the low temperature

of the first night starts a certain disintegration in the cranberry which is completed during the second night.

According to Prof. E. R. Lake,[a] low temperature congeals the watery part of the cell sap and also the intercellular water content of the plant. Within certain limits this is not or may not be injurious, providing the protoplastic contents of the cell are able to absorb the water and do this before the cell structure collapses as a result of insufficient cell turgor. Frequently the frosting of plants is followed by a sudden rise in temperature, in which case much of the water which was part of the cell sap in the normal condition of the plant escapes through the cell wall into intercellular spaces, or even from the plant entirely, and thus the protoplasm of the cell being unable to assume its normal condition becomes disorganized and decomposition follows.[b]

Disadvantage from reflowing.—It was possible to reflow only a portion of the Berlin marsh previous to frosts, and reflowing was seldom attempted there, as the drainage was poor, and the water could not be drained off quickly. As the picking season advances the water becomes colder and it is consequently more trying on the cranberry pickers. When a marsh has been reflowed the pickers on the day following seldom start work until noon, in order to avoid the dampness, as they object to working in a wet marsh and sometimes refuse to do so. Where the drainage is poor, the cranberry grower has sometimes to decide between leaving his marsh dry and risking the damage from frost, or reflowing and chancing the desertion of his pickers. In either case, the harvest is affected. It is important that as many pickers as possible be held until after the crop is gathered. On the Appleton marsh at Mather there is usually ample water supply and fairly good drainage under ordinary circumstances, and it is invariably flooded in anticipation of frost. Aside from the discomforts caused to the pickers working in a wet marsh, frequent reflowing softens the terminal buds, so that they are easily bruised by the pickers, and the crop of the following year is seriously affected as a consequence.[c]

Special data in connection with forecasting frost in the cranberry marshes.—The subject of local conditions in the bogs having been treated in detail, it is important that the discussion now turn to the relation existing between the temperature in the bogs and the general weather conditions throughout the country, as shown by the daily weather maps. Reference now will be made to maps of various types, especially during the years 1906 and 1907, which have preceded critical conditions in the Wisconsin bogs, in order that assistance may be afforded the forecaster and the cranberry grower in determining the probability and severity of frost.

Discussion of daily weather maps and local conditions in connection with frosts in the Wisconsin bogs in 1906.—Observations in the bogs during the season of 1906 were of course incomplete, although some data from Mather, Berlin, and Cranmoor are available from May 21 to the end of the season. It may be well now to refer to the severe frost which occurred on May 28, and the light frosts on June 11, 12, and 13 of that year, in connection with the weather maps issued at that time.

The weather map of May 27 shows a storm central over the southern portion of Illinois and Indiana, and a high-pressure area in Manitoba, encircled by a 30.2-inch isobar, with temperatures in the Dakotas and at Moorhead of about 40°. General rains prevailed throughout Wisconsin on May 27, with strong northeast to north winds. The maximum temperatures in shelters at Berlin, Mather, and Cranmoor were, respectively, 47°, 54°, and 53°. On the morning of the 28th the storm center had passed to the Middle Atlantic coast, while the high-pressure area had moved to the western Lake Superior region, a ridge extending southward over the Middle States. The pressure in the Wisconsin moorlands was approximately 30.15 inches, and the wind was light northeast with clear weather. The minimum temperatures were 21° at Mather, 29° at Berlin, and 28° at Cranmoor, with severe frosts at all three marshes.

The frosts of June 11, 12, and 13, 1906, were the only frosts which occurred during that month, and while they were not severe they nevertheless occurred at a critical time, and were

[a] Prof. E. R. Lake in Oregon Climate and Crop Bulletin, July, 1900.

[b] Professor A. G. McAdie states in Climatology of California (Bulletin L, U. S. Weather Bureau) that fruit growers in California have found it advantageous to interpose some screen early in the morning between the sun's rays and the frosted fruit.

[c] In many bogs the berries are gathered by raking instead of picking.

remarkable for their duration. The weather maps for June 10, 11, 12, and 13 furnish an explanation of these persistently low temperatures. On the morning of June 10 the barometer was low in both the northeastern and southeastern portions of the country, and a high-pressure area was centered at Winnipeg, where the barometer was 30.2 inches and the temperature below 50°. The HIGH moved eastward over the northern Lake region, steadily increasing in magnitude. On the morning of the 13th it reached from the St. Lawrence to the upper Mississippi Valley, with the center in Ontario, and encircled by a 30.4-inch isobar, the pressure in the bogs being about 30.25 on the 11th and 30.30 on the 12th and 13th. There was but little barometric gradient in the moorland sections on the mornings of June 11, 12, and 13; the wind was light from the northeast, and the weather clear both day and night. The appended table shows the maximum shelter temperatures on June 10, 11, and 12, and the minimum temperatures on the bog on June 11, 12, and 13.

	Maximum temperatures in shelter.				Minimum temperatures on bog.[a]		
	Mather.	Berlin.	Cranmoor.		Mather.	Berlin.	Cranmoor.
1906.	°	°	°	1906.	°	°	°
June 10	74	71	70	June 11	28	35	35
June 11	72	66	68	June 12	28	33	34
June 12	71	67	68	June 13	26	33	31

[a] At Berlin and Cranmoor the minimum thermometers were not at this time located at the coldest places on the marshes. At the coldest point the temperature ordinarily had to fall to 28° or 29° before frost was observed.

Frost was observed in the three cranberry marshes and generally throughout the moorlands on these days. The minimum temperature readings at Mather better represent the general temperature conditions than those at Berlin and Cranmoor, as the thermometer readings at the latter place were affected by water from reflowing, and moreover the thermometer at Berlin was not at that time located in the "ferns," the coldest point on the bog. The Berlin minimum readings above are for Station 2, which it was later found averaged 3° to 4° higher than in the "ferns." These frosts disappeared before sunrise each morning as the temperature rose.

No soil observations are available to show the temperature of the soil in the marshes at that time, as the soil thermometers had not been installed. However, there is no doubt that the temperature of the soil was low, and had much to do with the occurrence of the frost. There had been no unusually warm weather in the season of 1906 previous to June 10 that would serve to heat the soil to any great extent. It was found in the observations of 1907 that there was an irregular increase in soil temperature from the beginning of the season to about the middle of August. In that year the soil temperatures at the 3-inch depth in the peat bog at Mather on the corresponding dates in June were not above 52.5°, as compared with a maximum of 69.5° on August 12. During the middle and late summer, when the maximum air temperatures in the shade reach 70° or higher, there is ordinarily little probability of frost the ensuing night, because under such conditions the soil is heated considerably beneath the direct rays of the sun. At other times during the season maximum temperatures as high as 75° may be succeeded by frost. Frost very seldom occurs in the summer months on a night following a clear sunshiny day, and it can occur under these circumstances probably not later than June 15. Had the weather conditions of this period, as far as pressure, clear sky, and maximum temperature are concerned, occurred during July or August, frost would not have formed, because the ground would have been warm enough to prevent the temperature at its surface from falling to the freezing point.

During this period of three days in 1906 several of the growers retained the water over their marshes both day and night, or at least up to the surface, thus saving the supply of water which might otherwise have become exhausted. Unless the cold is expected to continue, growers after reflowing begin to drain off the water at daybreak, because if it remains on the bog during

a warm sunshiny day there is danger of scalding the berries and vines. No additional frosts occurred at Mather in the summer of 1906, and the first frost in the autumn was on September 14.

This first frost at Mather in September, 1906, was a light one. The pressure at the time was 30.24 inches, rising, and the preceding day, the 13th, had been partly cloudy with 77 per cent of sunshine, while the night had been clear, there being, however, a light fog during the early morning of the 14th. The temperature had been steadily falling since the 11th, a maximum of 90° having occurred on that date. On the 13th the highest temperature in the shade was 68°, and the temperature of the soil had been much reduced; in fact, it was lower at 6 p. m. at all stations on the bog than on any previous evening in September. At the time of the minimum temperature of 31° on the 14th there was an absolute calm on the bog. A fresh breeze had been blowing from the north the day before, partially evaporating the moisture produced by the rain which had fallen on the 12th, and as a consequence lowering the temperature at the surface of the soil.

Reference to the weather map of the 13th shows that the high-pressure area was then centered over the eastern portion of South Dakota, the center being inclosed by a 30.2-inch isobar with temperatures as low as 40°. The barometer rose rapidly in the moorland sections during the day, the center of the HIGH moving directly eastward to the Lake Superior region, where the pressure was 30.4 inches on the morning of the 14th. Had the soil been colder, the general conditions prevailing on the 14th would have caused a more severe frost; for, although the temperature of the soil had been lowered, as already stated, it had previously been very warm as a result of the hot wave of several days' duration.

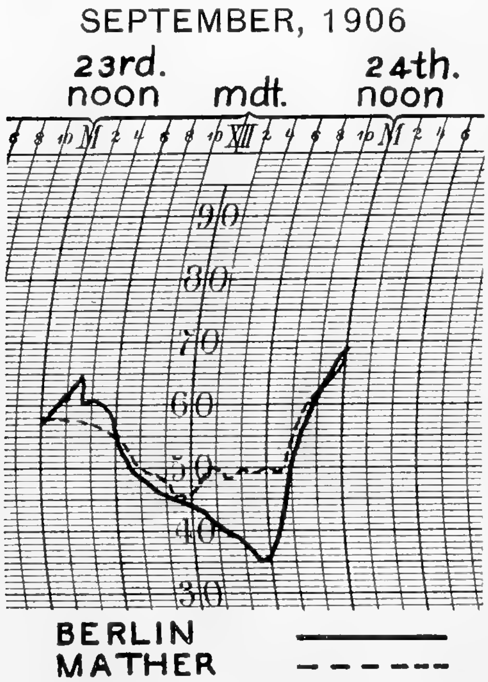

FIG. 29.—Mather and Berlin, Wis. Traces of thermograph in shelter from noon, September 23 to noon, September 24, 1906.

While frost occurred in the marsh at Berlin on the morning of September 24, the lowest "exposed" temperature at Mather was only 38°. The conditions seemed to be very favorable for low temperature in all moorland sections, but the clear weather at Mather on the night of September 23 was followed by increasing cloudiness before midnight, and the temperature, which had previously been falling, rose until 2 a. m., and then remained nearly stationary until 5 a. m. of the 24th. (Figure 29 shows the thermograph traces in shelter, Station 1, at each marsh.) The area of high barometer passed eastward with its center over Lake Superior, and was followed by a low-pressure area in the far Northwest. A light wind from the north prevailed at Berlin, which was nearer to the center of the high, while at Mather, located farther west, the wind had shifted to the southeast with increasing cloudiness under the influence of the LOW in the northwest, referred to above.

The first *severe* frost at Mather in the fall of 1906 occurred on the morning of September 27, and this was followed by another frost on the 28th. In both cases heavy dew was observed on the uplands, but no frost. Frosts, however, were general on both these dates in all the Wisconsin cranberry marshes. The barometer at Mather on the morning of the 27th was 30.36 inches, rising, and 30.16 inches on the morning of the 28th, falling. The night of the 26th–27th was clear, while the night of the 27th–28th was partly cloudy, and, probably because of the partial cloudiness, the minimum temperature, 31°, on the 28th was not as low as the minimum temperature of the 27th, 28°. Rain had occurred on the night of the 25th–26th, followed by a fresh wind during the daytime of both the 26th and the 27th. The maximum temperature in the shade on the 26th was 68°, and 69° on the 27th. Of course, this was late in the season,

and with clear weather the maximum temperatures would have been much higher if the days had been longer. The soil temperatures had been steadily falling, and on the 28th the lowest 6 p. m. readings of the month up to that time were recorded. The center of the high-pressure area on the 26th was well to the north, as shown by the weather map, with freezing temperatures in the British Northwest. The temperature at Moorhead, Minn., on the morning of the 27th was as low as 38°.

Heavy frost again occurred in all the Wisconsin bogs on the mornings of September 30 and October 1. Light rain had occurred at Mather September 28, and a fresh wind from the north prevailed during the daytime of the 29th, with cloudy weather and 67 per cent of sunshine. The maximum temperature on the 29th in the shelter at Station 1 at Mather reached only 67°. The barometer, which was only slightly above normal on the morning of the 29th, 30.04 inches, rose steadily during the day and night, reaching a height of 30.42 inches on the morning of the 30th. Frost began to appear in portions of the Mather marsh at 10 o'clock on the night of the 29th, and it was general over the entire marsh on the following morning, the minimum temperature at Station 2 over the moss being 25°, and 32° in the shelter at Station 1. On the morning of the 30th light fog lay over the marsh. Although the weather was clear on the 30th, the maximum temperature in the shade reached only 65°, and the soil temperature remained low on the 29th and the 30th. The exposed minimum temperature on the morning of October 1 at Station 2 was 25°.

The weather maps of September 29 and 30 and October 1 should be studied in connection with these frosts. An area of high barometer of great magnitude covered the Northwestern States, the 30.4-inch isobar inclosing the Dakotas and the eastern portions of Montana and Wyoming, and freezing temperatures were reported in North Dakota. The movement of the HIGH was directly eastward, reaching the western Lake region and Upper Mississippi Valley by the morning of the 30th, and the St. Lawrence Valley by October 1. On the latter date the barometer remained high over Wisconsin, as a ridge reached westward over the Lake region from the St. Lawrence Valley. A tropical storm, which had on the 27th caused great destruction at Mobile, was pushing northward through the interior of the country, and had advanced as far as St. Louis by the morning of the 29th. The high pressure area, however, moving directly southeastward, crossed its path and forced the LOW backward to the Gulf coast. The shifting of these areas brought down the cold air in a great mass over the Middle States on the morning of September 30.

Discussion of daily weather maps and local conditions in connection with frosts in the Wisconsin bogs in 1907.—Table 21 has been made quite comprehensive in order to show all the weather conditions that may be needed in connection with the study of the occurrence of frost in the bogs at Mather during the season of 1907. It is intended to supplement the tables which have preceded, and may be used in connection with Mather observations of various kinds. The barometric pressure, rainfall, wind velocity and direction, state of weather both day and night, and the amount of sunshine are most important in addition to temperature data.

In 1907 the observations began on May 12. During the balance of that month there were eight days on which the temperature "in the open" at Station 2 fell to freezing or below. On May 19, although the temperature was as low as 28°, no frost was seen, and on the 27th, when a temperature of 27° occurred, none was seen, although thin ice was observed early in the morning. A so-called "dry freeze," however, is often more dreaded by the cranberry grower than a heavy hoar frost. Nevertheless, it is evident that these "exposed" minimum temperatures at Station 2 were considerably lower than the actual temperature of the air. Low temperatures are so common in the Wisconsin bogs during the month of May and the first decade of June that it should not be necessary to make any special reference to the weather maps for that period. During the spring and early summer comparatively low temperatures often occur when the barometer is below normal, but never in midsummer. The lowest temperatures, moreover, almost invariably occur with high barometer. On May 20 and 21, for instance, when temperatures of 18° and 21°, respectively, were reported, the pressure was 30.30 inches and 30.32 inches.

The frost of June 8 was severe, the minimum temperature at Station 2 being 28°. The moss on the bog was frozen hard in places, and there was a heavy coating of frost on the instruments and vegetation. The air over the bog was calm, and the wind on the upland, 7 miles an hour from the north. The minimum temperature in the shelter at La Crosse, Wis., was 48°. The weather the day before, June 7, was cloudy and threatening, with a maximum of 64° in the shade. The unsettled conditions cleared away at 9 p. m and the pressure increased. On the morning of the 8th the center of the high-pressure area was over the Lake Superior region, and the barometer on the bog was 30.04 inches. Although the temperature was as low on the 1st and the 6th, only light frost was observed on these dates.

The last frost in June was on the 14th. On the morning of the 13th an area of high pressure was located over the Lake Superior region, the highest reading being 30.16 inches, at Port Arthur. This area seemed to spread southward, and had settled over Wisconsin by the morning of the 14th, with a pressure at Mather of 30.10 inches. The maximum temperature in the shelter at Station 1 was 75°, about 5° above the average maximum that may be expected on days preceding frost. There was a quick recovery in temperature during the daytime of the 14th, the maximum reaching 81°. The lowest temperature at Station 2 on the 14th was 31°, while the minimum at La Crosse was 50°.

On July 2 the lowest temperature at Station 2 was 29°. There was a heavy dew in the morning, but no frost was observed. Light frost may have occurred in portions of the marsh before daybreak; if so, it disappeared before the observer reached the bog. The sky on the previous night was clear and the pressure on the morning of the 2d was 30.10 inches. A calm prevailed on the bog, and the wind velocity and direction was 5 miles, north, on the upland. The minimum temperature at La Crosse was 50°. A fresh northwest wind had prevailed the the day before in the bog region, accompanied by sprinkles of rain, while the maximum temperature in the shade was 71°. Reference to the weather map of July 1 shows a generally unsettled condition from the Lakes westward to the eastern slope of the Rockies. The pressure in the latter section was 30.14 inches and this gradually shaded off to a low pressure of 29.70 inches in the St. Lawrence Valley. The barometric gradient was not decided, but the conditions prevalent on the 1st were sufficient to cause fresh northwest winds. The lowest temperature reported from any station in the Northwest was 44° at Minnedosa. On the morning of the 2d the high-pressure area reached in a wide belt from the Lake Superior region southwestward over Wisconsin, Iowa, and Nebraska to Colorado; and on that morning in the bog region the wind had fallen to practically a calm.

No freezing temperatures were observed again at Mather until September 9 and 10, when 30° was recorded at Station 2, but no frost was noted on either of these dates. On the weather map on the morning of the 8th appeared a seemingly typical condition—a low-pressure area over Lake Michigan and a high-barometer area encircled by a 30.30-inch isobar over the northern Rocky Mountain region. Temperatures were as low as 38° at Moorhead and Devils Lake. During the ensuing twenty-four hours the HIGH moved slightly southeastward, retaining its magnitude, but the LOW over the Lake region moved but little and lost force, the pressure in the center being 29.90 inches, as compared with 29.78 inches the previous morning, September 8. Frost was reported on the morning of September 9 from the regular Weather Bureau stations at Devils Lake, Bismarck, Williston, and Havre, with minimum temperatures of 36°. An unusual change in the general conditions occurred during the 9th, as both the high and the low pressure areas moved directly southward. Frosts were still prevalent in the Northwest, with persistently low temperatures, but cloudiness prevailed over the bog region on the nights of September 9 and 10 and prevented any severe freeze. While the temperature was 30° on the bogs on both these dates, readings of 45° and 46°, respectively, were reported from La Crosse. The maximum temperature in the shade at Mather was 65° on the 8th and 68° on the 9th. The barometer on the two mornings was 30.02 inches and 30.04 inches, respectively. There was but 50 per cent of sunshine on the 8th, the day being partly cloudy, and as a consequence the soil was not heated materially. The general weather conditions in the Northwest seemed

to be ideal for producing severe frost in the Wisconsin bogs on both the 9th and the 10th, and it was prevented only by the cloudiness.

A temperature of 30° was again recorded over the moss at Station 2 on September 21, but no frost was observed. The barometer was just normal, 30 inches, and some cloudiness had occurred during the previous night. The maximum temperature on the 21st was only 62°, but the temperature fell rapidly after sunset, a minimum of 23° being recorded over the moss at Station 2 on the morning of the 22d. There was a well marked low pressure area over Lake Superior on the morning of the 20th, the barometer being 29.50 inches at Marquette, while a high encircled by a 30.20 inch isobar covered the northern Rocky Mountain region. The HIGH moved directly eastward, so that on the morning of the 21st it extended from the Rocky Mountains to the Missouri River valley, and killing frosts and freezing temperatures were reported from North Dakota. This area then moved southeastward during the next twenty-four hours, and on the 22d it was centered in Missouri, the highest barometer being at Kansas City, 30.18 inches. The barometer at Mather on the morning of the 22d was 30.08 inches. While the minimum temperature over the moss at Station 2 was 23°, in the shelter at Station 1 it was 31°, and at La Crosse, 38°. On the 21st on the moorlands partly cloudy weather prevailed with 70 per cent. of sunshine, and a fresh northwest wind which died away to a calm on the bog by the morning of the 22d. Killing frosts were general on the marshes on the 22d; some frost was observed even the night before at 10.30 p. m.

Killing frosts were again reported in the bogs on the 25th, 26th, 29th, and 30th, and light frost on the 27th, as two areas of high pressure, one after another, pushed from the northern Rocky Mountain region southeastward over the central valleys. The temperature was so low within these areas that general frosts occurred on the uplands of the Middle States on September 25, 26, and 30. The nights, of course, were gradually becoming longer and the soil was growing colder, making the occurrence of frost more likely. The minimum temperature at Station 2 on the morning of the 30th was 19°, and frost was very heavy. The pressure was 30.32 inches, the wind very light from the west, and there had been only 33 per cent of sunshine the day before. The frosts of the 25th and 26th occurred also with high pressure, but on the mornings of the 27th and 29th, the barometer was but slightly above the normal. The minimum temperature at La Crosse on September 30 was 36°.

The cranberry marsh at Mather was reflowed in anticipation of these September frosts, and the sections that had not been picked were reflowed from time to time during the first half of October. Frosts, of course, were quite frequent during the month of October; so frequent, in fact, that it is not necessary to make any special study of these conditions in connection with the weather maps. Picking usually terminates early in October, and frost warnings are therefore not needed. The observations, however, were continued until the end of October, in order to complete the meteorological record for the season, insuring data up to the time that frost enters the ground. Moreover, after the crop has been picked, the observations were free from the complications usually arising from reflowing. The temperature over the moss at Station 2 during the month of October fell below freezing twenty-four out of the thirty-one days, the lowest temperature being 10° on October 28. On that date, the minimum temperature at La Crosse was 22°. The first ice was noted on October 8, and snow fell on the 19th. Damp ground was frozen on the 18th, and ice in the main reservoir was noted on the 21st, the minimum temperature on the latter date being 13°.

From a study of Table 21, it will be observed that frosts occurred usually on clear and comparatively calm mornings, with pressure above the normal. While high barometer is apparently not essential in the spring and early summer and in the autumn, frost never occurs during the warm months of July and August, and the first decade of September, while the ground is warm, except with a pressure considerably above the normal. Table 21 has been made comprehensive in order to afford opportunity for those interested to study in detail the subject of the temperature conditions in the bogs.

TABLE 21.—DAILY WEATHER CONDITIONS, MATHER, WIS., 1907.

MAY.

	Barometer—Rising (R), falling (F), stationary (S).		Relative humidity.				Dew-point, 7 p. m.		Rainfall.			Wind.				
	7 a. m.	7 p. m.	7. a. m.		7 p. m.		Upland.	Marsh.	7 a. m.	7 p. m.	Total.	Prevailing direction.	Average velocity.		Direction and velocity at time of minimum temperature.	
			Upland.	Marsh.	Upland.	Marsh.							Upland.	Marsh.	Upland.	Marsh.
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12	29.78–F	*29.44–S*	66		37		33		T.	T.	T.	S	20.3	9.9	SE 18	8
13	*29.46–S*	29.52–S	52	51	64	69	50	58	T.	0	T.	SW	16.3	7.3	SW 22	5
14	29.62–S	29.58–F	95	94	96	100	45	46	0.57	0.15	0.72	NW	7.5	4.4	NW 14	3
15	29.56–S	29.70–R	97	100	92	100	37	39	.24	.02	.26	W	9.8	6.3	W 10	8
16	29.80–R	29.80–F	85	92	79	96	50	53	.01	.03	.04	SW	10.9	5.7	W 8	3
17	29.82–S	29.80–R	90	92	35	47	36	41	.26	0	.26	NW	8.0	4.4	N 7	1
18	29.88–S	29.88–R	57	59	32	46	28	33	0	0	0	NW	14.7	8.6	NW 7	2
19	30.00–R	30.06–R	49	47	52	45	29	24	0	0	0	NW	14.5	8.1	NW 6	2
20	30.30–R	*30.24–S*	52	48	47	60	29	32	0	0	0	NW	8.0	4.0	NW 5	2
21	*30.32–S*	30.16–F	76	72	54	54	39	38	0	T.	T.	SW	7.2	3.3	N 1	Calm.
22	29.96–F	29.94–S	84	91	83	91	47	47	1.65	.01	1.66	NE	8.6	4.5	SW 8	2
23	30.08–S	30.08–F	89	92	71	82	44	46	0	0	0	E	10.7	5.4	N 8	5
24	30.12–S	30.00–F	76	78	58	59	40	40	0	T.	T.	E	16.6	8.6	NE 12	2
25	29.78–F	29.60–F	83	87	95	97	46	47	.03	.14	.17	NE	14.4	7.5	NE 16	7
26	29.60–S	29.80–F	97	100	100	100	35	36	.02	[a].08	[a].10	NW	12.3	7.7	N 8	4
27	30.00–S	30.06–S	50	62	39	48	28	32	T.	0	T.	NW	16.4	10.1	NW 12	6
28	30.06–F	29.94–S	57	55	51	50	43	40	0	0	0	SW	14.2	6.5	SW 5	1
29	30.00–S	29.96–R	56	53	53	55	43	43	0	0	0	SW	7.3	3.1	SW 2	Calm.
30	30.00–F	29.98–S	86	88	53	53	46	46	0	0	0	SE	7.0	3.4	NE 5	Calm.
31	30.02–R	29.94–F	68	71	40	40	34	34	.10	0	.10	E	11.5	5.5	NE 7	1
Means			74	75	63	68	39	41	[b]2.88	[b].43	[b]3.31	NW	11.8	6.2	NW 9	3.1

[a] Part snowfall. [b] Total.

Marsh wet and water in ditches high last half of month, due to frequent periods of cloudy and showery weather. Heavy rain on the 22d together with flooding on the night of the 26th caused surface water to remain around Station 7 from the 22d to June 2, inclusive.

Means for humidity and dew point for nineteen days.

Highest and lowest readings are in italics.

Table 21.—Daily Weather Conditions, Mather, Wis., 1907.

MAY.

Temperature.				Weather.			Miscellaneous.
Shelter Station 1, Upland.		Station 2, minimum.[a]	Difference—Minimum from minimum.	Previous night.	Day.	Per cent of sunshine.	
Maximum.	Minimum.						
81	36	35	− 1	Cloudy	Partly cloudy	52	Weather cleared after noon; distant lightning observed in evening.
81	*64*	*60*	− 4	Clear	do	73	Clear morning; partly cloudy afternoon; cloudy night with distant lightning.
48	45	45	0	Cloudy	Cloudy	0	Showery, thunderstorm conditions.
41	36	36	0	do	do	0	Low, dense clouds continuous; light fog blowing across marsh 7 to 7.40 a. m.
65	35	34	− 1	do	Partly cloudy	36	Cloudy until 10 a. m., partly cloudy to cloudy remainder of day; distant thunder and lightning in evening.
71	40	32	− 8	Partly cloudy	do	86	Light fog early a. m. to 6.40 a. m.
68	48	32	*−16*	Clear	Clear	89	Increasing cloudiness by night.
53	39	28	−11	do	Partly cloudy	87	Partly cloudy during day with strato-cumulus clouds.
56	28	*18*	−10	do	Clear	92	Increasing cloudiness late in afternoon. *Frost in morning*, ice in portions of ditches, ground frozen in moist sections. Fog over ditches and reservoir 7 to 8 p. m.
65	*27*	21	− 6	do	Partly cloudy	69	Gradually increasing cloudiness during day, overcast after 2.30 p. m., heavy thunder before midnight. *Heavy frost in morning.*
53	45	44	− 1	Cloudy	Cloudy	1	Low clouds. Heavy thunderstorm in morning.
57	44	44	0	do	do	9	Clearing after sunset.
59	44	40	− 4	do	do	11	Alto-stratus clouds.
49	45	44	− 1	do	do	0	Stratus clouds; light fog 6 p. m. into the night.
48	43	45	+ *2*	do	do	0	Frequent snow flurries with rain in evening.
55	32	27	− 5	Partly cloudy	Clear	85	*Thin ice observed this morning. No hoar frost seen.*
69	34	27	− 7	Clear	do	100	*Frost in morning.*
72	41	30	−11	do	Partly cloudy	77	Light dew in morning.
68	45	36	− 9	Partly cloudy	do	45	Do.
68	47	45	− 2	Cloudy	do	68	
61.3	40.9	36.2	−4.7			49	

[a] In open over bog.

Highest and lowest readings are in italics.

TABLE 21.—DAILY WEATHER CONDITIONS, MATHER, WIS., 1907—Continued.

JUNE.

	Barometer—Rising (R), falling (F), stationary (S).		Relative humidity.				Dew-point, 7 p. m.		Rainfall.			Wind.				
	7 a. m.	7 p. m.	7 a. m.		7 p. m.		Up-land.	Marsh.	7 a. m.	7 p. m.	Total.	Prevailing direction.	Average velocity.		Direction and velocity at time of minimum temperature.	
			Up-land.	Marsh.	Up-land.	Marsh.							Up-land.	Marsh.	Upland.	Marsh.
1	29.90–F	29.76–F	57	58	40	49	40	43	0	0	0	NE	9.9	4.3	NE 8	1
2	29.74–S	29.72–S	56	56	44	52	46	48	0	0	0	SW	6.2	2.8	NE 4	Calm.
3	29.70–R	29.70–R	90	91	78	79	52	51	T.	0.26	0.26	SW	7.4	3.2	S 7	4
4	*29.56–F*	29.66–R	96	91	81	73	44	42	0	T.	T.	NW	10.9	6.7	W 1	Calm.
5	29.86–R	29.94–R	74	68	37	49	36	39	0.05	0	.05	NW	15.8	8.9	NW 12	8
6	30.02–F	29.94–F	54	60	50	64	45	48	0	0	0	S	6.7	3.3	SW 2	Calm.
7	29.88–S	29.92–S	61	60	49	66	38	42	0	0	0	SE	10.8	4.8	SE 8	3
8	30.04–S	30.04–R	64	71	40	48	39	42	0	0	0	E	9.7	4.0	N 7	Calm.
9	30.00–F	29.84–F	53	57	51	53	47	46	0	0	0	SE	15.5	7.1	E 6	Calm.
10	29.62–F	*29.48–R*	77	80	94	96	60	61	.06	.57	.63	E	16.2	7.9	E 22	10
11	29.64–R	29.70–R	72	72	90	94	54	54	0	.02	.02	SW	9.3	3.9	S 4	1
12	29.82–R	29.92–S	92	90	80	85	51	54	0	0	0	NE	9.4	4.1	N 7	Calm.
13	29.98–R	30.00–R	78	74	42	53	46	50	0	0	0	NE	9.3	4.1	NE 6	Calm.
14	30.10–R	*30.06–F*	63	60	44	80	51	60	0	0	0	SE	6.7	2.8	NE 7	Calm.
15	30.12–F	30.00–R	75	95	45	46	56	56	0	0	0	SW	8.0	3.2	NE 5	Calm.
16	30.12–F	*30.06–S*	69	61	66	70	70	70	0	0	0	SW	13.4	5.4	SW 5	Calm.
17	*30.14–S*	*30.06–R*	79	72	64	80	64	67	0	T.	T.	SW	10.6	4.9	SW 8	2
18	30.10–S	*30.06–R*	95	93	74	79	64	64	.08	0	.08	NW	5.4	3.0	NW 4	Calm.
19	30.00–F	29.90–S	77	74	54	72	56	61	0	0	0	NW	5.4	2.7	NW 6	1
20	29.90–F	29.88–R	76	70	61	72	58	60	0	0	0	SW	6.0	2.7	W 3	Calm.
21	29.94–F	29.88–R	70	74	89	95	64	64	0	.13	.13	SE	8.2	4.0	SE 3	Calm.
22	29.90–S	29.82–S	92	96	82	82	67	67	.22	T.	.22	SW	12.2	5.7	SE 10	3
23	29.90–S	29.86–R	90	93	87	98	63	65	.07	T.	.07	S	7.1	3.3	S 6	1
24	29.94–F	29.88–S	92	97	76	92	66	69	0	T.	T.	S	6.0	2.8	N 3	Calm.
25	29.86–R	29.92–S	84	83	55	61	48	51	.68	T.	.68	NW	10.6	5.8	NW 5	Calm.
26	30.00–S	30.02–S	78	70	60	88	49	54	0	0	0	NW	10.2	5.8	NW 10	7
27	30.06–F	29.94–F	81	69	65	90	56	61	0	0	0	W	5.9	2.8	NW 4	Calm.
28	29.92–F	29.82–S	93	90	68	76	58	59	0	0	0	SW	6.0	2.4	NW 1	Calm.
29	29.84–S	29.76–S	62	72	72	78	64	65	0	T.	T.	SW	7.4	2.9	S 4	Calm.
30	29.80–F	29.70–R	73	69	94	95	64	62	0	.13	.13	SW	10.2	4.3	S 5	Calm.
Means	....	....	76	76	64	74	54	56	[a] 1.16	[a] 1.11	[a] 2.27	SW	9.2	4.3	NW 6.1	1.4

[a] Total.

Marsh continued wet fore part of month, and flooding occurred on the nights of the 5th and 13th. Decidedly warmer weather set in immediately after the 13th, and by the end of the month the marsh was considerably drier and the water in the ditches about normal.

Highest and lowest readings are in italics.

Table 21.—Daily Weather Conditions, Mather, Wis., 1907—Continued.

JUNE.

Temperature. Shelter Station 1, Upland. Maximum.	Temperature. Shelter Station 1, Upland. Minimum.	Temperature. Station 2, minimum.[a]	Temperature. Difference—Minimum from minimum.	Weather. Previous night.	Weather. Day.	Weather. Per cent of sunshine.	Miscellaneous.
72	36	*28*	− 8	Clear	Clear	100	*Light frost in morning.*
77	39	29	*−10*	do	Partly cloudy	80	Heavy dew in morning; fog over marsh before sunrise. Distant lightning in evening.
61	55	53	− 2	Cloudy	Cloudy	13	Partly cloudy in evening.
70	41	35	− 6	do	Partly cloudy	51	Dense fog in early morning; heavy gale after 3 p. m.
68	44	38	− 6	Partly cloudy	Clear	100	
72	*34*	*28*	− 6	Clear	Partly cloudy	73	*Light frost* in morning. Moss and moist ground frozen; strawberry leaves on uplands frosted. Heavy dew observed in spots.
64	48	45	− 3	Cloudy	do	42	Clearing after 9 p. m.
75	36	*28*	− 8	Clear	do	90	*Frost in morning.* Moss frozen hard in places. Some instruments, especially thermographs, heavily coated with frost.
72	41	32	− 9	Partly cloudy	Cloudy	31	Distant thunder in early morning.
66	54	53	− *1*	Cloudy	do	8	
62	47	39	− 8	do	do	10	
63	53	50	− 3	Partly cloudy	do	33	Heavy dew began to form before sundown.
75	44	34	*−10*	Clear	Clear	100	Heavy fog over marsh in evening.
81	39	31	− 8	do	do	100	Heavy dew in morning; *frost observed in patches.*
82	43	35	− 8	do	Partly cloudy	94	Heavy dew in morning.
91	54	46	− 8	do	do	92	
94	*70*	*63*	− 7	Partly cloudy	do	79	
83	59	50	− 9	do	do	63	Thunderstorm conditions.
84	57	47	*−10*	Clear	Clear	100	
83	51	42	− 9	do	do	99	Heavy dew and dense fog over marsh in early morning.
84	49	41	− 8	Partly cloudy	Partly cloudy	73	Thunderstorm conditions.
80	61	59	− 2	Cloudy	do	50	
76	60	54	− 6	Partly cloudy	Cloudy	54	
87	54	50	− 4	do	Partly cloudy	80	Thunderstorm conditions. Heavy dew and dense fog in morning.
71	58	53	− 5	Cloudy	do	72	
70	48	41	− 7	Clear	Clear	100	Heavy dew and dense fog over marsh in evening.
77	45	35	*−10*	do	do	100	Heavy dew and dense fog over marsh in early morning and again at night.
79	43	37	− 6	do	do	93	Heavy dew and dense fog over marsh in early morning.
82	51	43	− 8	Partly cloudy	Partly cloudy	77	Thunderstorm conditions.
83	58	49	− 9	Clear	do	68	Do.
76.1	49.1	42.3	−6.8			71	

[a] In open over bog.

Highest and lowest readings are in italics.

TABLE 21.—DAILY WEATHER CONDITIONS, MATHER, WIS., 1907—Continued.

JULY.

	Barometer—Rising (R), falling (F), stationary (S).		Relative humidity.				Dew-point, 7 p. m.		Rainfall.			Wind.				
	7 a. m.	7 p. m.	7 a. m.		7 p. m.		Upland.	Marsh.	7 a. m.	7 p. m.	Total.	Prevailing direction.	Average velocity.		Direction and velocity at time of minimum temperature.	
			Upland.	Marsh.	Upland.	Marsh.							Upland.	Marsh.	Upland.	Marsh.
1.......	29.86-R	29.98-R	83	83	76	79	53	53	T.	T.	T.	NW	11.6	7.0	NW 8	3
2.......	30.10-F	30.06-S	76	76	58	65	50	51	0	0	0	{NE SW}	4.5	1.8	N 5	Calm.
3.......	30.10-F	29.90-S	98	96	90	96	67	65	0.35	0.35	0.70	SW	8.6	3.7	SW 3	Calm.
4.......	30.00-S	29.94-F	76	95	88	100	66	65	0	.03	.03	SE	10.1	5.1	SE 2	Calm.
5.......	29.82-S	29.84-R	80	86	93	90	70	70	2.15	.01	2.16	N	7.3	4.0	SE 9	3
6.......	29.92-R	29.90-R	88	95	56	78	56	60	0	0	0	NW	5.5	2.8	NW 3	1
7.......	29.90-F	29.82-R	78	78	91	83	67	69	0	0	0	SW	5.9	2.7	W 2	Calm.
8.......	29.92-S	29.92-R	77	65	66	77	62	63	0	0	0	NW	6.8	3.5	NW 4	1
9.......	29.96-S	29.90-S	72	71	62	68	57	59	0	0	0	NW	5.6	2.9	NW 4	2
10.......	29.92-F	29.82-S	90	89	81	82	59	59	0	.05	.05	NE	4.5	2.0	N 5	Calm.
11.......	29.84-R	29.92-R	94	98	70	76	60	60	.03	T.	.03	{NE NW}	6.0	3.4	NE 3	1
12.......	30.04-S	30.00-F	81	81	70	77	60	61	0	0	0	SE	4.8	1.9	N 4	Calm.
13.......	29.94-F	29.80-S	79	72	60	69	62	62	0	0	0	SW	11.4	4.8	S 4	Calm.
14.......	29.74-S	29.72-S	87	95	85	91	69	68	.18	.02	.20	SW	10.1	5.1	S 8	2
15.......	*29.54-F*	29.74-R	96	100	74	93	64	66	.52	.13	.65	NW	10.4	5.8	SE 12	7
16.......	29.92-S	29.88-S	93	98	80	92	70	70	0	.02	.02	SW	7.5	3.6	N 4	Calm.
17.......	30.06-S	*30.10-S*	76	83	56	81	56	63	0	0	0	NW	8.9	5.0	NW 5	1
18.......	*30.12-S*	30.00-F	92	98	69	86	62	64	0	.03	.03	SE	5.6	2.3	NW 4	Calm.
19.......	29.94-F	29.90-R	95	96	72	91	67	66	.09	0	.09	W	8.2	4.5	SE 4	Calm.
20.......	29.98-S	29.96-R	86	83	58	95	62	69	0	0	0	NW	5.2	2.6	W 6	2
21.......	29.90-F	29.70-S	97	98	99	100	68	68	.89	3.89	4.78	S	7.2	3.5	S 4	Calm.
22.......	29.86-R	29.96-R	91	93	70	91	61	63	.02	0	.02	NW	9.0	5.2	NW 5	3
23.......	29.98-F	29.84-F	84	80	82	93	67	67	0	T.	T.	SW	6.3	2.8	N 3	Calm.
24.......	29.80-S	29.80-S	76	76	61	91	60	64	0	0	0	NW	7.5	4.0	SW 5	2
25.......	29.78-F	*29.66-R*	82	94	87	92	64	65	0	.02	.02	SW	8.8	4.9	N 2	Calm.
26.......	29.98-S	30.02-S	74	75	93	93	68	60	0	0	0	NW	8.3	4.8	N 8	4
27.......	30.04-F	29.90-F	83	85	70	76	59	60	0	0	0	SW	5.4	2.5	W 2	Calm.
28.......	29.84-F	29.76-R	74	74	64	66	59	60	T.	0	T.	W	9.6	5.2	SW 5	Calm.
29.......	29.92-S	29.94-R	86	81	59	75	53	56	0	0	0	NW	9.4	5.0	NW 9	3
30.......	29.98-F	29.92-S	74	74	86	89	66	66	0	.20	.20	NW	8.6	4.5	NW 4	Calm.
31.......	29.92-S	29.86-F	76	80	54	95	57	62	0	0	0	NW	9.2	4.8	NW 8	3
Means	....	....	84	85	75	85	62	63	a 4.23	a 4.75	a 8.98	NW	7.7	3.9	NW 5.0	1.2

a Total.

With the exception of a heavy rain on the 5th which kept the water in the ditches high for several days, the condition of the marsh during the first half of the month was nearly normal. A period of showery weather set in on the 14th, culminating in an unusually heavy rain on the 21st, which completely flooded the marsh and raised the water in the reservoir 4 inches above high-water mark. This was further augmented by the breaking down of a dam on the marsh above. Station 7 was covered with water to a depth of nearly 12 inches for three days after the 21st, and the water did not entirely disappear until the 1st of August.

Highest and lowest readings are in italics.

TABLE 21.—DAILY WEATHER CONDITIONS, MATHER, WIS., 1907—Continued.

JULY.

Temperature.				Weather.			Miscellaneous.
Shelter Station 1, Upland.		Station 2, minimum.[a]	Difference—Minimum from minimum.	Previous night.	Day.	Per cent of sunshine.	
Maximum.	Minimum.						
71	59	52	−7	Cloudy	Partly cloudy	72	Heavy dew in evening.
74	*38*	*29*	−9	Clear	Clear	100	Heavy dew in morning. No frost observed, but *light frost* probably occurred in portions of marsh before daybreak.
85	48	38	−10	Partly cloudy	Partly cloudy	59	Dense fog in early morning and previous night. Severe thunderstorm conditions in vicinity.
77	51	45	−6	Clear	do	51	Severe thunderstorm in evening with hail and heavy rain, flooding marsh and injuring cranberries.
84	60	59	−1	Partly cloudy	do	70	Thunderstorm conditions in morning.
79	58	53	−5	Cloudy	do	67	Dense fog in early morning, clearing about 2 p. m.
84	51	43	−8	Clear	Clear	90	Distant thunderstorm in evening.
82	59	47	*−12*	do	Partly cloudy	68	
79	61	51	−10	Cloudy	Cloudy	68	
79	50	42	−8	Partly cloudy	do	35	
79	60	60	*0*	Cloudy	Partly cloudy	46	
81	51	42	−9	Partly cloudy	do	91	
83	54	44	−10	do	do	71	
82	62	56	−6	Cloudy	Cloudy	40	
79	*68*	*68*	*0*	do	do	47	Clearing toward night.
81	51	46	−5	Partly cloudy	do	38	Distant lightning in evening.
80	57	45	*−12*	Clear	Clear	100	
77	50	44	−6	Partly cloudy	Cloudy	29	
84	56	52	−4	Cloudy	Partly cloudy	66	Thunderstorm in early morning.
85	61	50	−11	Clear	do	84	
72	64	60	−4	Cloudy	Cloudy	0	Heavy thunderstorm flooding marsh and reservoir.
79	64	57	−7	Partly cloudy	Partly cloudy	75	
81	53	49	−4	Clear	do	79	Distant thunderstorm in evening.
81	64	59	−5	do	Clear	100	
85	53	49	−4	Partly cloudy	Partly cloudy	56	
75	49	42	−7	do	Clear	100	
75	45	41	−4	do	Cloudy	57	
81	59	55	−4	Cloudy	Partly cloudy	82	
77	57	48	−9	Clear	Clear	97	
82	53	45	−8	do	Partly cloudy	80	Thunderstorm in afternoon.
79	58	48	−10	do	Clear	94	Cloudy in evening.
79.7	55.6	49.0	−6.6			68	

[a] In open over bog.

Highest and lowest readings are in italics.

TABLE 21.—DAILY WEATHER CONDITIONS, MATHER, WIS., 1907—Continued.

AUGUST.

	Barometer—Rising (R), falling (F), stationary (S).		Relative humidity.				Dew-point, 7 p. m.		Rainfall.			Wind.				
	7 a. m.	7 p. m.	7. a. m.		7 p. m.		Up-land.	Marsh.	7 a. m.	7 p. m.	Total.	Prevailing direction.	Average velocity.		Direction and velocity at time of minimum temperature.	
			Up-land.	Marsh.	Up-land.	Marsh.							Up-land.	Marsh.	Upland.	Marsh.
1	29.72-F	*29.72-S*	97	97	87	91	52	49	0.51	0.09	0.60	NW	12.8	7.4	NW 5	Calm.
2	29.88-R	29.94-R	90	91	72	80	52	54	.01	T.	.01	NW	9.9	5.9	NW 10	4
3	30.04-R	30.04-S	88	92	65	90	49	54	0	0	0	NW	6.3	3.4	NW 8	3
4	30.06-F	29.86-F	90	98	67	72	54	56	0	0	0	SW	9.9	4.8	S 3	Calm.
5	29.74-R	29.88-R	97	92	71	91	57	59	.10	0	.10	W	11.9	6.5	SW 11	7
6	30.02-F	29.90-R	82	88	86	92	70	71	T.	.05	.05	SW	12.8	5.2	S 5	Calm.
7	30.04-R	30.06-S	79	72	62	90	58	62	0	0	0	NW	6.0	3.3	NW 10	4
8	30.16-F	30.08-S	90	96	86	91	59	60	0	T.	T.	SE	8.3	4.1	S 3	1
9	30.08-F	30.00-S	73	76	79	89	70	69	T.	0	T.	S	6.2	2.9	SE 5	Calm.
10	30.00-F	29.84-F	62	82	72	72	71	72	0	0	0	S	11.5	5.8	S 6	Calm.
11	*29.70-S*	29.76-R	88	87	64	71	56	57	.06	.54	.60	SW	12.6	6.6	SW 7	5
12	30.02-R	30.00-S	66	73	56	77	56	58	0	0	0	NW	9.4	4.6	NW 8	Calm.
13	30.18-R	30.20-R	82	84	54	73	58	59	0	0	0	NW	4.8	2.2	NW 11	5
14	*30.28-S*	30.10-S	76	93	81	92	64	64	T.	0	T.	SE	7.9	3.5	NE 4	Calm.
15	30.00-F	29.80-F	80	77	81	88	66	66	0	T.	T.	S	10.8	5.3	S 10	2
16	29.80-R	29.88-R	88	88	55	48	60	54	1.35	0	1.35	SW	15.0	8.5	SW 5	2
17	30.04-S	30.06-R	64	77	57	86	60	59	0	0	0	NW	5.3	2.2	NW 6	1
18	30.16-F	29.96-F	85	86	74	82	67	68	0	0	0	SW	15.9	8.6	SW 6	Calm.
19	29.90-S	30.00-R	76	76	70	69	54	52	2.28	.34	2.62	SE	12.2	6.6	SE 6	2
20	*30.28-S*	*30.22-S*	69	81	69	95	47	49	0	0	0	NW	7.5	4.0	NW 12	1
21	30.24-S	30.14-F	73	86	69	79	53	53	0	0	0	SW	3.8	1.7	SW 2	Calm.
22	30.20-F	30.00-F	85	91	76	63	56	51	0	0	0	SW	8.5	3.5	SW 3	Calm.
23	29.90-F	*29.72-R*	78	62	82	84	67	67	0	T.	T.	SW	12.8	5.7	SW 5	1
24	29.90-R	29.92-R	64	67	51	70	52	52	.37	0	.37	SW	13.5	7.4	SW 10	3
25	30.04-F	29.96-F	74	83	57	87	52	58	0	0	0	NW	6.8	3.6	NW 5	2
26	29.94-S	29.76-F	91	95	97	99	57	56	0	.78	.78	SE	7.5	3.6	E 10	1
27	29.80-R	29.92-R	97	98	83	89	63	64	T.	0	T.	SW	4.4	2.4	SW 3	2
28	30.04-R	30.00-S	69	89	83	85	64	63	0	0	0	W	2.5	1.0	NE 4	Calm.
29	29.98-S	29.90-S	69	95	95	93	64	64	0	T.	T.	SE	5.5	2.5	SE 2	Calm.
30	29.98-R	30.00-R	92	97	56	86	54	67	.24	T.	.24	NW	3.2	1.4	N 2	1
31	30.14-F	30.08-S	97	88	76	80	74	76	.05	T.	.05	SE	7.3	3.3	E 4	Calm.
Means			81	86	72	82	59	60	[a] 4.97	[a] 1.80	[b] 6.77	SW, NW	8.8	4.4	SW, NW 6.2	1.5

[a] Total.

Marsh continued wet and water in the ditches high all of the month.

Highest and lowest readings are in italics.

TABLE 21.—DAILY WEATHER CONDITIONS, MATHER, WIS., 1907—Continued.

AUGUST.

Temperature. Shelter Station 1, Upland. Maximum.	Temperature. Shelter Station 1, Upland. Minimum.	Station 2, minimum.[a]	Difference—Minimum from minimum.	Weather. Previous night.	Weather. Day.	Per cent of sunshine.	Miscellaneous.
68	55	47	− 8	Partly cloudy.	Partly cloudy.	49	Thunderstorm in early morning.
68	46	39	− 7	Cloudy	....do	55	
68	48	40	− 8	Clear	....do	90	Dense fog over marsh in evening.
74	*39*	34	− 5	Cloudy	....do	69	
79	59	58	− 1	....do	Clear	90	
84	54	46	− 8	Partly cloudy.	Partly cloudy.	47	Thunderstorm conditions.
80	57	48	− 9	Clear	Clear	94	
76	55	51	− 4	Partly cloudy.	Cloudy	18	
85	54	49	− 5	Cloudy	Clear	90	
89	59	55	− 4	Partly cloudy.	....do	83	Cloudy late in the evening.
80	*74*	*70*	− 4	Cloudy	Partly cloudy.	48	Heavy thunderstorm in morning.
79	53	40	−13	Clear	Clear	100	
81	50	42	− 8	....do	....do	95	Moderately heavy dew in morning.
85	53	46	− 7	Partly cloudy.	....do	80	
82	56	50	− 6	Clear	Partly cloudy.	84	Thunderstorm in evening. Light dew in morning.
79	61	58	− 3	Partly cloudy.	Clear	100	
85	52	43	− 9	Clear	....do	100	
84	57	48	− 9	....do	....do	100	Moderately heavy dew in morning.
74	65	65	0	Cloudy	Partly cloudy.	49	Thunderstorm conditions.
66	43	34	− 9	Clear	Clear	100	Dew began before sunset; fog over marsh in evening. Cloudy at midnight.
74	47	36	−11	Partly cloudy.	....do	91	Fog appeared over marsh at sunset.
74	43	34	− 9	Clear	....do	91	Heavy ground fog over marsh at 5 a. m.
78	54	47	− 7	Partly cloudy.	Partly cloudy.	92	Thunderstorm.
72	54	41	−13	....do	....do	92	
73	48	*33*	*−15*	Clear	Clear	95	
64	51	42	− 9	Partly cloudy.	Cloudy	10	
69	56	56	*0*	Cloudy	Partly cloudy.	36	
76	58	50	− 8	Clear	Clear	100	
68	51	44	− 7	Partly cloudy.	Cloudy	4	
75	64	62	− 2	Cloudy	Partly cloudy.	50	
89	58	52	− 6	....do	Clear	85	
76.7	54.0	47.1	−6.9			74	

[a] In open over bog.

Highest and lowest readings are in italics.

TABLE 21.—DAILY WEATHER CONDITIONS, MATHER, WIS., 1907—Continued.

SEPTEMBER.

	Barometer— Rising (R), falling (F), stationary (S).		Relative humidity.				Dewpoint, 7 p. m.		Rainfall.			Wind.				
	7 a. m.	7 p. m.	7. a. m.		7 p. m.		Up-land.	Marsh.	7 a. m.	7 p. m.	Total.	Pre-vail-ing direc-tion.	Average velocity.		Direction and velocity at time of minimum temperature.	
			Up-land.	Marsh.	Up-land.	Marsh.							Up-land.	Marsh.	Upland.	Marsh.
1.......	30.02–S	29.90–R	76	78	72	71	61	61	T.	0	T.	NW	11.1	6.2	NW 8	2
2.......	29.90–F	29.86–S	73	76	68	76	48	54	0	0	0	NW	11.0	6.2	NW 9	4
3.......	29.80–S	29.84–S	74	90	84	95	54	56	0.01	0.01	0.02	NW	8.0	4.5	NW 6	2
4.......	29.90–S	29.92–R	87	93	78	92	52	57	0	.03	.03	NW	9.1	5.3	NW 10	4
5.......	30.08–S	30.06–S	84	77	73	94	53	56	0	0	0	NW	7.8	4.0	NW 12	6
6.......	30.08–F	29.94–F	91	91	88	89	57	56	0	.04	.04	W	4.0	1.5	SW 2	Calm.
7.......	29.78–F	29.80–R	94	96	98	97	58	58	.31	T.	.31	E	5.6	2.8	E 10	6
8.......	29.82–S	29.92–R	96	98	81	94	49	52	.27	0	.27	NW	9.5	5.2	NW 6	2
9.......	30.02–R	30.08–R	76	80	70	70	49	48	0	0	0	NW	9.3	5.1	NW 12	3
10.......	30.04–S	29.96–F	92	91	76	95	51	53	0	.01	.01	NW	3.2	1.1	N 4	Calm.
11.......	29.94–R	29.98–R	87	92	62	78	54	59	0	0	0	NW	10.8	5.6	NW 4	1
12.......	30.12–R	30.12–S	80	80	75	79	59	61	0	T.	T.	SW	7.4	2.6	W 6	Calm.
13.......	30.14–R	30.00–S	74	76	67	82	61	66	0	0	0	SE	14.4	7.2	SW 2	Calm.
14.......	30.00–S	30.00–R	65	76	80	81	64	64	0	0	0	SW	14.5	5.9	SW 15	4
15.......	30.08–R	30.10–F	65	68	50	65	63	73	0	0	0	SW	10.4	4.5	W 6	1
16.......	30.00–S	30.04–R	96	96	75	86	63	67	.14	0	.14	SW	10.1	5.0	SW 13	4
17.......	30.04–S	29.98–F	97	97	97	98	63	63	.01	.75	.76	NE	11.5	5.8	SW 5	2
18.......	30.04–F	29.92–F	94	97	80	85	67	70	.25	T.	.25	SW	10.2	4.7	S 4	2
19.......	29.92–F	29.72–F	97	95	75	85	69	71	.40	0	.40	NE	14.0	6.8	NE 6	3
20.......	29.78–R	29.98–R	94	94	66	85	49	54	.41	0	.41	W	14.6	8.2	NW 17	13
21.......	30.00–S	30.06–S	74	81	47	73	31	36	0	0	0	SW	13.1	6.9	SW 4	1
22.......	30.08–F	29.76–F	56	77	94	94	49	50	0	T.	T.	SW	18.8	4.0	SW 4	1
23.......	*29.48–F*	*29.56–R*	89	95	65	80	48	54	.10	.14	.24	W	13.3	7.3	W 10	1
24.......	29.58–R	30.02–R	77	81	68	88	34	40	0	T.	T.	NW	19.5	11.4	NW 30	10
25.......	30.26–R	30.26–F	66	87	65	83	36	42	0	0	0	W	8.1	4.3	W 6	3
26.......	30.20–S	30.08–F	82	83	66	80	44	50	0	0	0	SW	8.2	3.1	SW 4	1
27.......	30.00–S	29.90–S	98	94	80	87	44	46	0	0	0	NE	10.2	4.8	NE 3	Calm.
28.......	29.88–S	29.96–S	92	74	52	74	38	46	0	0	0	NE	7.9	3.6	NE 9	5
29.......	30.02–S	30.06–R	70	72	87	94	46	49	0	.02	.02	NW	7.5	4.1	S 1	Calm.
30.......	*30.32–S*	*30.30–F*	71	86	81	95	40	39	0	0	0	S	5.1	2.0	W 3	2
Means.	....	....	82	86	74	85	52	55	[a] 1.90	[a] 1.00	[a] 2.90	NW	9.9	5.0	NW 7.7	2.8

[a] Total.

Marsh continued wet and water in ditches high all of the month, flooding in anticipation of frost being frequent during latter part of the month.

Highest and lowest readings are in italics.

TABLE 21.—DAILY WEATHER CONDITIONS, MATHER, WIS., 1907—Continued.

SEPTEMBER.

Temperature.				Weather.			Miscellaneous.
Shelter Station 1, Upland.		Station 2, minimum.[a]	Difference—minimum from minimum.	Previous night.	Day.	Per cent of sunshine.	
Maximum.	Minimum.						
80	*70*	61	− 9	Partly cloudy.	Clear	94	Cloudy in evening.
68	53	42	*−11*	do	do	100	
65	50	40	−10	do	Partly cloudy.	41	
66	52	45	− 7	Cloudy	do	60	
71	44	36	− 8	Clear	Clear	80	Fog began to form about 8 p. m.
67	41	33	− 8	Partly cloudy.	Cloudy	9	Fog quite dense in morning, especially over marshes; grass very wet from dew and fog.
64	54	55	*+ 1*	Cloudy	do	1	
65	56	56	0	do	Partly cloudy.	50	
68	40	30	−10	Clear	Clear	100	Dew began to form at 6 p. m.; light fog over marsh in evening.
64	38	30	− 8	Partly cloudy.	Cloudy	24	Although minimum temperature was low, no frost was observed.
73	45	37	− 8	do	Partly cloudy.	60	
78	48	37	*−11*	Clear	Clear	72	Increasing cloudiness in afternoon.
80	50	40	−10	Partly cloudy.	do	100	
82	62	57	− 5	Clear	do	93	
84	63	54	− 9	do	Partly cloudy.	88	
81	67	*64*	− 3	Cloudy	Clear	85	Thunderstorm in morning.
74	53	44	− 9	Partly cloudy.	Cloudy	31	Do.
79	58	56	− 2	Cloudy	Partly cloudy.	46	Thunderstorm conditions.
84	61	58	− 3	do	do	63	Thunderstorm in early morning.
66	60	57	− 3	do	Clear	72	
62	38	30	− 8	Partly cloudy.	Partly cloudy.	70	
64	31	23	− 8	Clear	do	70	*Killing frost* in morning; frost first observed last night at 10.30 on marsh.
62	45	37	− 8	Cloudy	Cloudy	18	
49	43	40	− 3	do	do	21	Clearing at night.
55	*28*	20	− 8	Clear	Clear	100	*Killing frost.*
63	34	25	− 9	Partly cloudy.	Partly cloudy.	38	Do.
55	34	27	− 7	Cloudy	Cloudy	0	*Light frost.*
60	37	35	− 2	do	Partly cloudy.	72	Ground fog on marsh after 5.45 p. m.
60	29	25	− 4	Partly cloudy.	Cloudy	33	*Killing frost.*
61	*28*	*19*	− 9	Clear	Partly cloudy.	86	*Killing frost, very heavy deposit.*
68.3	47.1	40.4	−6.7			59	

[a] In open over bog.

Highest and lowest readings are in italics.

TABLE 21.—DAILY WEATHER CONDITIONS, MATHER, WIS., 1907—Continued.

OCTOBER.

	Barometer — Rising (R), falling (F), stationary (S).		Relative humidity.				Dewpoint, 7 p. m.		Rainfall.			Wind.				
	7 a. m.	7 p. m.	7 a. m.		7 p. m.		Up-land.	Marsh.	7 a. m.	7 p. m.	Total.	Prevailing direction.	Average velocity.		Direction and velocity at time of minimum temperature.	
			Up-land.	Marsh.	Up-land.	Marsh.							Up-land.	Marsh.	Upland.	Marsh.
1	30.18–F	29.86–F	80	85	73	85	50	52	0	0.08	0.08	SE	13.0	6.5	SE 5	2
2	29.86–R	29.90–S	85	98	63	74	54	54	0.04	0	.04	SW	5.7	2.2	SW 6	1
3	29.86–S	29.80–R	89	94	88	97	54	56	.09	.01	.10	SW	7.6	4.0	NE 7	Calm.
4	29.96–S	29.88–S	86	89	60	57	41	36	.01	0	.01	W	8.6	4.4	W 5	2
5	29.98–R	30.00–F	58	68	94	95	50	49	0	0	0	NW	7.9	3.7	NW 6	2
6	29.80–F	*29.60–F*	77	74	56	89	48	55	0	0	0	SW	14.4	6.5	NW 6	1
7	*29.60–R*	29.94–R	90	96	88	92	44	44	.02	.06	.08	NW	11.4	6.5	NW 12	2
8	30.22–S	30.10–F	83	88	39	60	27	32	0	0	0	SW	8.7	3.8	SW 4	1
9	29.90–S	29.98–S	50	46	80	86	42	43	0	T.	T.	NW	15.9	8.1	NW 9	4
10	29.84–F	29.86–S	67	70	41	75	29	42	0	0	0	NW	16.2	8.9	NW 3	1
11	30.00–R	30.14–R	88	87	61	60	30	30	.03	T.	.03	NW	14.0	8.4	NW 10	7
12	30.28–S	30.32–S	85	89	77	86	31	32	0	0	0	NW	10.2	6.1	NW 12	7
13	*30.44–R*	30.32–F	82	80	56	84	28	26	0	0	0	NW	5.6	2.5	NW 4	3
14	30.28–F	30.12–S	62	81	56	53	38	36	0	T.	T.	SW	7.8	3.2	SW 5	Calm.
15	30.12–S	30.14–S	76	93	72	63	44	39	.10	0	.10	SW	8.0	3.8	SE 6	4
16	30.16–S	30.12–S	94	96	83	82	52	50	0	0	0	SW	5.4	1.9	SW 2	Calm.
17	30.08–F	30.10–R	81	70	51	44	46	36	0	0	0	SW	13.7	6.9	NW 6	Calm.
18	30.42–S	*30.40–F*	76	64	48	87	20	26	0	0	0	NW	8.8	4.8	NW 9	7
19	30.28–F	30.04–F	72	79	75	82	33	36	0	T.	T.	SW	5.6	2.6	NW 4	1
20	30.20–R	30.36–S	56	54	81	85	29	28	0	0	0	N	6.9	3.7	NE 9	4
21	30.42–F	30.10–F	78	84	65	87	34	41	0	0	0	SW	10.6	4.0	SW 3	1
22	29.90–F	29.94–R	57	79	72	87	48	45	0	0	0	W	11.7	5.7	NW 8	4
23	30.14–S	30.18–S	88	78	51	76	42	46	T.	T.	T.	SW	5.4	2.1	SE 6	1
24	30.14–F	29.98–R	46	87	47	77	29	35	0	0	0	SW	11.5	5.7	S 6	3
25	30.22–R	30.32–S	53	74	47	81	23	29	0	0	0	N	7.7	3.9	NW 8	3
26	30.22–F	29.90–F	93	89	56	64	32	35	0	T.	T.	SW	8.0	3.4	NW 6	1
27	29.94–R	30.26–R	91	90	58	61	20	20	T.	T.	T.	NW	14.7	8.7	NW 17	2
28	30.30–F	30.18–S	98	89	54	84	29	35	0	0	0	SW	6.1	2.4	SW 4	Calm.
29	30.16–S	30.22–S	78	71	92	88	40	40	0	T.	T.	E	8.7	4.1	NE 5	2
30	30.26–R	30.30–F	89	79	91	97	41	41	T.	.05	.05	SE	9.5	4.6	SE 7	3
31	30.26–F	30.14–F	92	90	72	56	43	35	.10	0	.10	SE	......	......	E 6	2
Means.	....	....	77	81	66	77	38	39	a.39	a.20	a.59	SW	9.6	4.8	NW 6.6	2.3

a Total.

Marsh was much drier this month than at any time previous this season, except in the latter part of June, although water in the ditches remained high until about the 10th of the month.

Highest and lowest readings are in italics.

TABLE 21.—DAILY WEATHER CONDITIONS, MATHER, WIS., 1907—Continued.

OCTOBER.

Temperature.				Weather.			Miscellaneous.
Shelter Station 1, Upland.		Station 2, minimum [a].	Difference—minimum from minimum.	Previous night.	Day.	Per cent of sunshine.	
Maximum.	Minimum.						
60	33	27	−6	Partly cloudy.	Cloudy	21	No frost or dew observed.
75	*52*	*45*	−7	Cloudy	Partly cloudy.	65	
70	46	36	−10	Partly cloudy.	Cloudy	15	
62	41	27	*−14*	do	Partly cloudy.	70	*Light frost.*
66	41	27	*−14*	Clear	Clear	83	Do.
74	44	34	−10	Partly cloudy.	do	85	
51	50	37	−13	do	Cloudy	0	
56	23	16	−7	Clear	Partly cloudy.	75	*Heavy and killing frost; looked like light snow; thin ice formed.*
52	40	33	−7	Cloudy	Cloudy	0	
60	35	25	−10	Partly cloudy.	Clear	72	No frost observed.
48	35	26	−9	do	Cloudy	11	
43	29	23	−6	Cloudy	do	13	*Heavy and killing frost; ice formed.*
50	25	16	−9	Clear	Clear	100	*Killing frost and ice;* aurora in evening.
62	22	16	−6	do	Partly cloudy.	70	*Killing and heavy frost and ice.*
60	44	39	−5	Cloudy	do	67	
69	36	29	−7	Partly cloudy.	do	47	Dense fog from last midnight until 11 a. m.
71	39	27	−12	Clear	Clear	89	Light fog in evening over marsh.
48	24	18	−6	do	do	100	*Killing frost,* light in amount, but damp ground froze.
43	27	18	−9	Partly cloudy.	Cloudy	0	*First snow* flurry of the season; *severe freeze.*
48	28	22	−6	do	Clear	100	*Freezing.*
54	19	13	−6	Clear	do	100	*Very heavy deposit of frost. Ice* on reservoir.
66	40	31	−9	Partly cloudy.	do	83	
57	30	22	−8	do	do	98	*Frost.*
64	29	18	−11	do	do	86	*Freezing.*
49	28	17	−11	Clear	do	100	*Frost.*
53	19	12	−7	Partly cloudy.	Partly cloudy.	69	*Heavy frost* in morning.
37	34	29	−5	Cloudy	Cloudy	0	Snow in morning.
53	*17*	*10*	−7	Partly cloudy.	Clear	100	*Exceedingly heavy frost deposit.*
49	32	26	−6	Clear	Cloudy	34	
45	37	35	*−2*	Cloudy	do	10	
56	37	29	−8	do	do	44	
56.5	33.4	25.3	−8.1			58	

[a] In open over bog.

Highest and lowest readings are in italics.

Comparison between temperatures in the bog at Mather, Wis., and at United States Weather Bureau Office, La Crosse, Wis.—While numerous references have been made to the minimum temperature readings at La Crosse, a more complete comparison between the temperature at that place and Mather should be of interest, especially to those who are well acquainted with the daily weather map. Forecasters must look to the forecast chart for their general information, and many of them are accustomed to consider reports from certain stations as "keys" to conditions prevailing in adjacent sections. La Crosse may be considered as a "key" to the cranberry marsh region of Wisconsin. It is situated about 55 miles southwest of Mather, and is an old established station of the Weather Bureau. The thermometers at La Crosse were at the time of this investigation located in an instrument shelter on the roof of the federal building. Thus far the study has been confined mainly to the temperature conditions in the bogs, showing the wide range in even the same bog; and references have been made to the general weather conditions prevailing as shown by the daily weather maps. Some mention has also been made of the temperature readings at La Crosse in connection with the marsh readings in Wisconsin, and now a comparison of observations of temperature at both La Crosse and Mather for the entire season of 1907, Tables 22 and 22*a* should prove interesting. The maximum temperature readings are not included in the table, as a comparison of them does not seem to be important.

The minimum shelter readings at Station 1 at Mather averaged 5.2° lower than at La Crosse (Table 22*a*), and the average difference was greatest in June, 7.1°, and least in September, 3.6°. The temperature in the shelter over the moss at Station 2 on the bog averaged 8.7° lower than at La Crosse, and the greatest monthly difference was again in June, 10.8°, and the least in September, 6.4°. The minimum exposed over the moss at the height of 5 inches on the bog averaged 11.9° lower than at La Crosse, and the greatest monthly difference was in June, 13.9°, and the least in May, 8.5°. The minimum in the open on the bog at Mather averaged 3.2° lower than that in the shelter nearby. The greatest difference on any one day in the various months between the temperature at La Crosse and that in the open over the moss at Mather was 20° in May, 24° in June, 21° in July, 19° in August, 20° in September, and 22° in October. Often there were days of very little difference when the weather was cloudy, and there were a few instances where the temperature in the bog at Mather was even higher than at La Crosse. This is not surprising in view of the fact that these stations are 55 miles apart, and that occasionally the weather conditions at the two places differ considerably. What we should consider in the study of these readings is the average difference under all conditions, the average difference when the pressure is high and the weather clear, and the extreme differences. While extreme differences of 22 to 24 degrees may occur, there are usually days in every month when the temperature in the bog is 20° lower than at La Crosse. The average difference when the weather is clear and the pressure high is about 18°, so that when the temperature at La Crosse is 50° during the conditions favorable for frost, it is probable that the temperature at the coldest places on the bog is as low as 32°. The latter has reference, however, to the reading of a minimum thermometer in the open, and ordinarily, the reading of the exposed minimum at the coldest point in the bog must be below 30° to cause any damage. On August 8, 1904, when the minimum temperature at La Crosse was 48°, the memorable midsummer freeze occurred which destroyed the greater portion of the Wisconsin crop, minimum temperatures in the bogs being as low as 26°. Frost usually formed on the thermograph before it did on the vegetation, indicating that the black metal cover of the instrument loses heat even more rapidly than the vines and grasses. Again, temperatures of 30°, 29°, and even 28° have been observed when no frost was seen, but unless frost is looked for on such mornings at the very time of minimum temperature, there is no proof that frost did not occur. When the temperature is below freezing for a brief period only, light frost may form for a few minutes just before daybreak, and disappear as soon as the temperature rises to the melting point. Even should frost occur during any night in summer, the temperature would have risen above the freezing point by sunrise.

TABLE 22.—MINIMUM TEMPERATURES AT WEATHER BUREAU, LA CROSSE, WIS., AND AT DIFFERENT LOCATIONS AT MATHER, WIS., SEASON OF 1907.

Day of month.	May.							June.						
	Readings from Weather Bureau office, La Crosse, Wis.	Shelter on upland, Mather, Wis.		Shelter on marsh, over moss, Mather, Wis.		At 5 inches above marsh, over moss, in open, Mather, Wis.		Readings from Weather Bureau office, La Crosse, Wis.	Shelter on upland, Mather, Wis.		Shelter on marsh, over moss, Mather, Wis.		At 5 inches above marsh, over moss, in open, Mather, Wis.	
		Readings.	Difference.	Readings.	Difference.	Readings.	Difference.		Readings.	Difference.	Readings.	Difference.	Readings.	Difference.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1								*45*	36	− 9	32	−13	*28*	−17
2								47	39	− 8	32	−15	29	−18
3								55	55	0	54	*−1*	53	*− 2*
4								48	41	− 7	38	−10	35	−13
5								49	44	− 5	42	− 7	38	−11
6								46	*34*	−12	*31*	−15	*28*	−18
7								50	48	− 2	47	− 3	45	− 5
8								48	36	−12	31	−17	*28*	−20
9								56	41	*−15*	36	*−20*	32	*−24*
10								58	54	− 4	54	− 4	53	− 5
11								57	47	−10	44	−13	39	−18
12	45	36	− 9	37	− 8	35	−10	54	53	− 1	51	− 3	50	− 4
13	*56*	*64*	*+ 8*	*61*	*+ 5*	*60*	+ 4	49	44	− 5	37	−12	34	−15
14	41	45	+ 4	45	+ 4	45	+ 4	50	39	−11	35	−15	31	−19
15	36	36	0	36	0	36	0	55	43	−12	39	−16	35	−20
16	37	35	− 2	35	− 2	34	− 3	65	54	−11	49	−16	46	−19
17	50	40	−10	35	−15	32	−18	*68*	*70*	*+ 2*	*66*	− 2	*63*	− 5
18	50	48	− 2	35	−15	32	−18	65	59	− 6	52	−13	50	−15
19	42	39	− 3	33	− 9	28	−14	59	57	− 2	50	− 9	47	−12
20	*33*	28	− 5	*21*	−12	*18*	−15	58	51	− 7	45	−13	42	−16
21	41	*27*	*−14*	23	*−18*	21	*−20*	59	49	−10	45	−14	41	−18
22	46	45	− 1	44	− 2	44	− 2	66	61	− 5	61	− 5	59	− 7
23	47	44	− 3	44	− 3	44	− 3	66	60	− 6	58	− 8	54	−12
24	50	44	− 6	42	− 8	40	−10	62	54	− 8	54	− 8	50	−12
25	48	45	− 3	45	− 3	44	− 4	63	58	− 5	56	− 7	53	−10
26	40	43	+ 3	45	*+ 5*	45	*+ 5*	54	48	− 6	46	− 8	41	−13
27	38	32	− 6	31	− 7	27	−11	52	45	− 7	39	−13	35	−17
28	41	34	− 7	31	−10	27	−14	56	43	−13	41	−15	37	−19
29	50	41	− 9	34	−16	30	*−20*	62	51	−11	45	−17	43	−19
30	53	45	− 8	39	−14	36	−17	64	58	− 6	51	−13	49	−15
31	50	47	− 3	46	− 4	45	− 5							
Means	44.7	40.9	−3.8	38.1	−6.6	36.2	−8.5	56.2	49.1	−7.1	45.4	−10.8	42.3	−13.9

NOTE.—Columns headed "Difference" have in every case reference to the readings at the La Crosse office as compared with readings at the various exposures at Mather.

Highest and lowest readings are in italics.

TABLE 22.—MINIMUM TEMPERATURES AT WEATHER BUREAU, LA CROSSE, WIS., AND AT DIFFERENT LOCATIONS AT MATHER, WIS., SEASON OF 1907—Continued.

Day of month.	July.							August.						
	Readings from Weather Bureau office, La Crosse, Wis.	Shelter on upland, Mather, Wis.		Shelter on marsh, over moss, Mather, Wis.		At 5 inches above marsh, over moss, in open, Mather, Wis.		Readings from Weather Bureau office, La Crosse, Wis.	Shelter on upland, Mather, Wis.		Shelter on marsh, over moss, Mather, Wis.		At 5 inches above marsh, over moss, in open, Mather, Wis.	
		Readings.	Difference.	Readings.	Difference.	Readings.	Difference.		Readings.	Difference.	Readings.	Difference.	Readings.	Difference.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	58	59	+1	55	−3	52	−6	53	55	+2	52	−1	47	−6
2	*50*	*38*	−12	*32*	*−18*	*29*	*−21*	52	46	−6	43	−9	39	−13
3	59	48	−11	41	*−18*	38	*−21*	51	48	−3	43	−8	40	−11
4	65	51	*−14*	47	*−18*	45	−20	*50*	*39*	*−11*	*36*	−14	34	−16
5	*70*	60	−10	61	−9	59	−11	63	59	−4	59	−4	58	−5
6	64	58	−6	55	−9	53	−11	64	54	−10	48	*−16*	46	−18
7	61	51	−10	46	−15	43	−18	61	57	−4	51	−10	48	−13
8	65	59	−6	50	−15	47	−18	63	55	−8	53	−10	51	−12
9	64	61	−3	54	−10	51	−13	62	54	−8	52	−10	49	−13
10	60	50	−10	45	−15	42	−18	*69*	59	−10	57	−12	55	−14
11	62	60	−2	*60*	−2	60	−2	63	*74*	*+11*	*72*	*+9*	*70*	+7
12	59	51	−8	44	−15	42	−17	58	53	−5	43	−15	40	−18
13	63	54	−9	47	−16	44	−19	60	50	−10	46	−14	42	−18
14	63	62	−1	61	−2	56	−7	62	53	−9	49	−13	46	−16
15	66	*68*	*+2*	*68*	*+2*	*68*	*+2*	64	56	−8	54	−10	50	−14
16	62	51	−11	49	−13	46	−16	64	61	−3	59	−5	58	−6
17	61	57	−4	48	−13	45	−16	58	52	−6	47	−11	43	−15
18	60	50	−10	47	−13	44	−16	66	57	−9	51	−15	48	−18
19	67	56	−11	53	−14	52	−15	58	65	+7	65	+7	65	+7
20	64	61	−3	53	−11	50	−14	50	43	−7	39	−11	34	−16
21	66	64	−2	62	−4	60	−6	52	47	−5	40	−12	36	−16
22	66	64	−2	60	−6	57	−9	51	43	−8	38	−13	34	−17
23	60	53	−7	54	−6	50	−10	61	54	−7	51	−10	47	−14
24	69	64	−5	61	−8	59	−10	57	54	−3	45	−12	41	−16
25	65	53	−12	53	−12	49	−16	52	48	−4	38	−14	*33*	*−19*
26	58	49	−9	46	−12	42	−16	59	51	−8	46	−13	42	−17
27	57	45	−12	45	−12	41	−16	60	56	−4	55	−5	56	−4
28	63	59	−4	57	−6	55	−8	60	58	−2	54	−6	50	−10
29	61	57	−4	51	−10	48	−13	61	51	−10	48	−13	44	−17
30	57	53	−4	46	−11	45	−12	66	64	−2	64	−2	62	−4
31	62	58	−4	53	−9	48	−14	*69*	58	*−11*	55	−14	52	−17
Means	62.2	55.6	−6.6	51.7	−10.5	49.0	−13.2	59.3	54.0	−5.3	50.1	−9.2	47.1	−12.2

NOTE.—Columns headed "Difference" have in every case reference to the readings at the La Crosse office as compared with readings at the various exposures at Mather.

Highest and lowest readings are in italics.

TABLE 22.—MINIMUM TEMPERATURES AT WEATHER BUREAU, LA CROSSE, WIS., AND AT DIFFERENT LOCATIONS AT MATHER, WIS., SEASON OF 1907—Continued.

Day of month	September.							October.						
	Readings from Weather Bureau office, La Crosse, Wis.	Shelter on upland, Mather, Wis.		Shelter on marsh, over moss, Mather, Wis.		At 5 inches above marsh, over moss, in open, Mather, Wis.		Readings from Weather Bureau office, La Crosse, Wis.	Shelter on upland, Mather, Wis.		Shelter on marsh, over moss, Mather, Wis.		At 5 inches above marsh, over moss, in open, Mather, Wis.	
		Readings.	Difference.	Readings.	Difference.	Readings.	Difference.		Readings.	Difference.	Readings.	Difference.	Readings.	Difference.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	62	*70*	+ 8	65	+ 3	61	− 1	49	33	*−16*	32	−17	27	*−22*
2	55	53	− 2	47	− 8	42	−13	*55*	52	− 3	*49*	− 6	*45*	−10
3	56	50	− 6	45	−11	40	−16	53	*46*	− 7	40	−13	36	−17
4	53	52	− 1	45	− 8	45	− 8	44	41	− 3	32	−12	27	−17
5	50	44	− 6	41	− 9	36	−14	45	41	− 4	33	−12	27	−18
6	50	41	− 9	38	−12	33	−17	*55*	44	−11	39	−16	34	−21
7	59	54	− 5	56	− 3	55	− 4	40	50	*+10*	41	+ 1	37	− 3
8	47	56	+ 9	56	+ 9	56	*+ 9*	32	23	− 9	21	−11	16	−16
9	45	40	− 5	36	− 9	30	−15	40	40	0	39	− 1	33	− 7
10	46	38	− 8	36	−10	30	−16	40	35	− 5	29	−11	25	−15
11	49	45	− 4	42	− 7	37	−12	39	35	− 4	32	− 7	26	−13
12	52	48	− 4	40	−12	37	−15	33	29	− 4	28	− 5	23	−10
13	60	50	−10	44	*−16*	40	*−20*	25	25	0	21	− 4	16	− 9
14	64	62	− 2	59	− 5	57	− 7	34	22	−12	20	−14	16	−18
15	*66*	63	− 3	58	− 8	54	−12	47	44	− 3	43	− 4	39	− 8
16	63	67	+ 4	*66*	+ 3	*64*	+ 1	44	36	− 8	34	−10	29	−15
17	61	53	− 8	48	−13	44	−17	44	39	− 5	30	−14	27	−17
18	62	58	− 4	58	− 4	56	− 6	32	24	− 8	23	− 9	18	−14
19	*66*	61	− 5	61	− 5	58	− 8	32	27	− 5	23	− 9	18	−14
20	50	60	*+10*	59	*+ 9*	57	+ 7	32	28	− 4	27	− 5	22	−10
21	42	38	− 4	35	− 7	30	−12	28	19	− 9	18	−10	13	−15
22	38	31	− 7	29	− 9	23	−15	42	40	− 2	35	− 7	31	−11
23	47	45	− 2	43	− 4	37	−10	34	30	− 4	27	− 7	22	−12
24	40	43	+ 3	43	+ 3	40	0	40	29	−11	23	*−17*	18	*−22*
25	*33*	*28*	− 5	*25*	− 8	20	−13	30	28	− 2	24	− 6	17	−13
26	45	34	*−11*	29	*−16*	25	*−20*	29	19	−10	18	−11	12	−17
27	42	34	− 8	32	−10	27	−15	25	34	+ 9	32	+ 7	29	*+ 4*
28	43	37	− 6	39	− 4	35	− 8	*22*	*17*	− 5	*16*	− 6	*10*	−12
29	40	29	*−11*	29	−11	25	−15	42	32	−10	29	−13	26	−16
30	36	*28*	− 8	*25*	−11	*19*	−17	41	37	− 4	36	− 5	35	− 6
31								35	37	+ 2	34	− 1	29	− 6
Means	50.7	47.1	−3.6	44.3	−6.4	40.4	−10.3	38.2	33.4	−4.8	29.9	−8.3	25.3	−12.9

Highest and lowest readings are in italics.

TABLE 22a.—MONTHLY AND SEASONAL MEANS OF MINIMUM TEMPERATURES AT WEATHER BUREAU, LA CROSSE, WIS., AND AT DIFFERENT LOCATIONS AT MATHER, WIS., TOGETHER WITH DIFFERENCES BETWEEN THE READINGS, 1907.

Month.	Readings, La Crosse, Wis.	Shelter on upland, Mather, Wis.		Shelter on marsh, over moss, Mather, Wis.		At 5 inches above marsh, over moss, in open.	
		Readings.	Difference.	Readings.	Difference.	Readings.	Difference.
	°	°	°	°	°	°	°
May [a]	44.7	40.9	−3.8	38.1	− 6.6	36.2	− 8.5
June	56.2	49.1	−7.1	45.4	−10.8	42.3	−13.9
July	62.2	55.6	−6.6	51.7	−10.5	49.0	−13.2
August	59.3	54.0	−5.3	50.1	− 9.2	47.1	−12.2
September	50.7	47.1	−3.6	44.3	− 6.4	40.4	−10.3
October	38.2	33.4	−4.8	29.9	− 8.3	25.3	−12.9
Means	51.9	46.7	−5.2	43.2	− 8.7	40.0	−11.9

[a] Means for twenty days.

NOTE.—Columns headed "Difference" have in every case reference to the readings at the La Crosse office as compared with readings at the various exposures at Mather.

Temperature conditions in the bogs during the seasons of 1908 and 1909.—The principal features of the season of 1908 in the Wisconsin bogs were as follows: Frost occurred on June 11 and 15 at both Cranmoor and Mather, the exposed minimums in the bog at the latter station being 29°, and 28.9°, respectively; frost was again noted at both stations on August 20, 23, and 24; and again in September on the 2d and the 3d, the rest of the month being warm until the 28th when killing frost occurred; also on the 29th and 30th. There was ample water supply in the Wisconsin bogs for reflowing, and no damage, as a consequence, occurred to the crops from these frosts.

In 1909, frost occurred at Mather, June 15 and 18, but no frost was reported at Cranmoor on any date in June. Frost was again reported at Mather on July 19, when the lowest exposed minimum was 29°. On that date the lowest temperature at Cranmoor was 32.8°, but no frost was observed. On August 30, frost was observed at Mather, but none at Cranmoor, the minimum at Mather registering 23°. The temperature was unusually low in the bogs during September, in strong contrast to the September of 1908, frost being reported on 11 dates at both Mather and Cranmoor. On these days the exposed minimums over moss at Mather were as follows:

	°		°
September 1	15	September 25	14
September 2	16	September 26	13
September 6	22	September 27	12
September 16	24	September 28	26
September 23	24	September 30	22
September 24	22		

These conditions were most extraordinary, and following, as they did, a season of comparative drouth, the growers were unable to properly reflow their marshes. In fact the larger portion of the Wisconsin crop was destroyed by the frosts of September 1 and 2, 1909, not more than 25 per cent of the entire crop being eventually saved.

The conditions as shown by the weather map indicated plainly the coming of the frosts during the year 1909, and ample warnings were issued from the forecast center at Chicago. It is unfortunate that water supply was not available for reflowing, as in previous years. The season of 1909 in the moorland sections was the driest in about a dozen years, while in the few years immediately preceding, there was complaint of too much rainfall rather than of too little.

Temperature of the water in the reservoir.—Much has been said already about the low temperature prevailing over damp ground, and it has been shown that over a saturated soil the minimum temperature, especially on clear, cool nights is low. It may therefore seem strange that additional water is used in order to ward off frost. A reservoir usually has about three times the acreage of the bog that it is intended to flow or reflow. The time required to flow a marsh depends upon the head of water at the main gate of the reservoir, and upon the depth of the water already in the ditches. If the ditches are nearly empty, much time is required, but the Wisconsin growers usually have water in their ditches up to within about a foot of the surface of the marsh. Through capillarity this water rises through the peat, and if the water is within 6 inches of the top of the ditches the marsh is very wet. By pressing down upon the soil along the edge of the ditches, even though the water therein is considerably below the surface of the marsh, the water is squeezed out as from a sponge. During a dry, warm season, growers are accustomed to let the water remain low in the ditches, in order to save their supply, but as cold weather approaches it is the custom to turn on additional water from the reservoir. It is often possible to reflow an entire marsh in from two to four hours. The water in the reservoir is usually comparatively warm, and although it loses heat as it passes through the ditches on a cool night, light frost is sometimes avoided by merely increasing the depth of the water in the ditches. At other times, however, the water is raised just to the surface of the marsh, and only when a severe frost is expected are the vines and berries completely covered with water. The water turned onto the marsh on these occasions in anticipation of frost usually

has a high temperature as compared with the water that is found from day to day in the peat soil of the bog. This latter partakes of the temperature of the soil itself, and is one of the important factors in preventing the heating of that very soil in the daytime, and consequently one of the direct causes of the low minimum air temperatures at night. If the water is low in the reservoir, as happens during a drought, and during a cool period its temperature is reduced, nothing can be gained by flowing unless there is sufficient supply to completely cover the bog. To bring this cold water just to the surface would be to reduce the temperature of the air still further by evaporation. Reference has already been made to the drouth in the Wisconsin bogs in the summer of 1909. Few growers had sufficient water supply to reflow in anticipation of the severe frosts of September 1 and 2 of that year, and it has been said that the growers who did not attempt to reflow suffered less injury than those who used their limited supply of water, chilled as it must have been.

While, as has been stated before, in order to be effective, the acreage of the reservoir should be three times that of the cranberry marsh, the reservoir of the Fitch marsh at Berlin was hardly half the size. There are other marshes in Berlin that have no protection in the shape of reservoirs. The Sackett marsh depends upon the Fox River for its water supply, the water being pumped from the river whenever there is need of flowing or reflowing.

A Richard soil thermograph placed in the reservoir at the Appleton marsh, with its bulb about 12 inches below the surface, has furnished an interesting series of readings of water temperature for the season of 1907. (Fig. 14.) The temperature of the water responded to the varying changes in the temperature of the air. There was an irregular increase through June and July to the middle of August, the highest maximum occurring on August 7, 79°, with the exception of a maximum of 81° which occurred on June 17 and 24, during and following a protracted period of high temperature. The highest minimum, 73°, occurred on June 22 and August 11. The highest and the lowest temperatures each month were respectively as follows: May, 67° and 42°; June, 81° and 53°; July, 77° and 66°; August 79° and 58°; September, 70° and 46°; October, 60° and 35°. The absolute range for the season was therefore 46°. The following are the mean daily maximum and minimum temperatures each month: May, 58° and 49°; June, 70° and 63°; July, 74° and 69°; August, 70° and 64°; September, 61° and 55°; October, 49° and 42°. Throughout the season, the lowest temperature of the day usually occurred at about 5 a. m. and 6 a. m. The maximum occurred in May at 4 p. m., and as the season advanced it occurred later and later each day until midsummer, after which it gradually occurred earlier in the afternoon, so that in October the time of maximum was 2 p. m. The greatest daily range in the temperature of the water was 16° on June 1, and there were a number of days when the temperature varied only 2° or 3°, during cloudy weather. The lowest temperature in October, 35°, occurred on the night of the 27th–28th. Figures 26 and 27, previously referred to, show the relation existing between the temperature of the water in the reservoir and the temperature of the air and of the soil at Mather, Wis., for two selected weeks in 1906.

Observations were not made regularly of the temperature of the water in the ditches, but there is no doubt that on clear, cool nights it was much lower than that in the reservoir, as the latter had considerably less volume and lay in the midst of the cold bog. Observations made at Berlin on October 1, 1906, showed a temperature of 53° in the reservoir, and temperatures of 37° and 39° in two small ditches. The ditches at Berlin where these observations were taken were shallow, the water being scarcely more than a foot in depth. At Mather, on the other hand, the ditches were 3 feet in depth, and they were consequently able to carry a considerable volume of water.

While the water turned on from the reservoir into the ditches gradually loses heat, it, in turn, communicates heat to the marsh even before the surface of the marsh is covered. The thermograph sheet shows several instances when, after the water had been turned on, not only the fall in temperature over the bog was arrested, but a rise actually occurred for a brief period, although this was followed again by a fall. The thermograph sheet, at Station 3, in the open

for June 5–6, 1907, shows this graphically. (Fig. 30.) At about 10 p. m. the temperature had fallen to 37°; during the next two hours an irregular curve was described. At midnight the temperature had risen to 42°, after which it gradually fell. On the same night, the thermograph trace of the instrument at Station 5, on the bog, shows that from 10 p. m. until nearly midnight the fall in temperature was retarded somewhat. (Fig. 30.) The water in reflowing was colder upon reaching Station 5, as it was farther away from the reservoir than Station 3; moreover, on the night of June 5, the water was not so high in the section around Station 5 as around Station 3, on account of the slight difference in elevation of the two stations. The lowest temperature at Station 3 was 33°, while at Station 5 it was 32°. At Station 2, over moss and outside the cranberry marsh where flooding was not practiced, the minimum temperature was 28°. The temperatures at Stations 2 and 5 as a rule differed but little, as stated

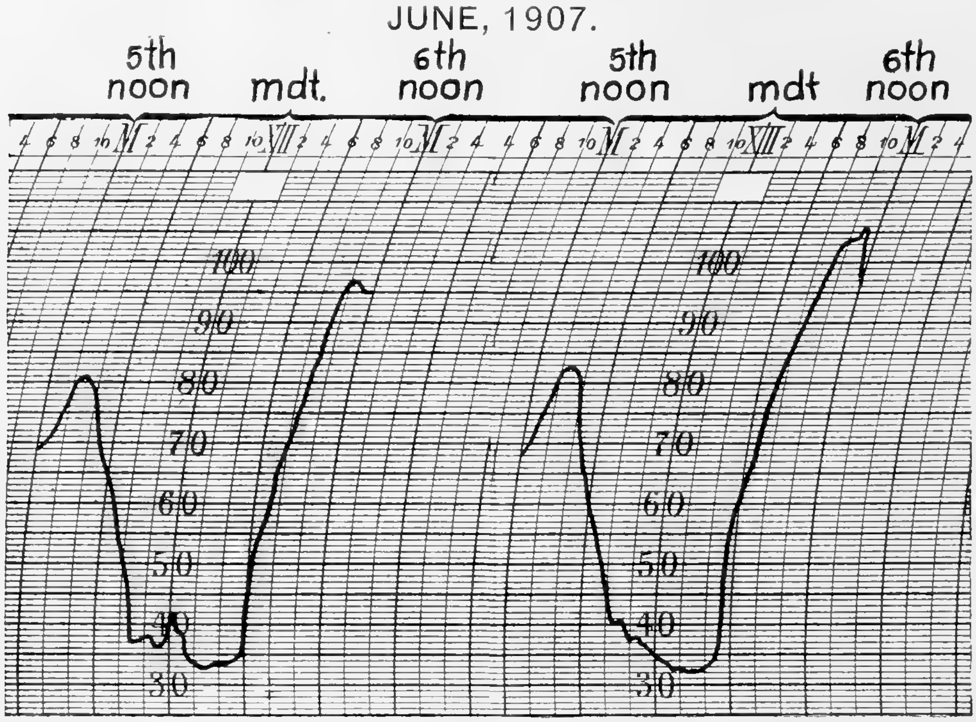

Fig. 30.

Station 3 Station 5

Thermograph trace in "open" over bog from noon, June 5, 1907, to noon, June 6, 1907, showing effect of flowing of marsh on temperature of air. Stations 3 and 5, Mather, Wis.

before, the average difference between the exposed minimums at the 5-inch height for the entire season of 1907 being but 0.1°. It is therefore probable that reflowing the marsh on this night was responsible for the difference in temperature of 4° between Stations 2 and 5.

CONCLUSION.

Advantages gained from sanding, draining, and cultivating.—It is obvious from a study of the observations presented in the foregoing tables that sanding, draining and cultivating serve to decidedly modify low night air temperatures; and it is strange, at first thought, that Wisconsin growers do not sand their marshes. Many of them, however, object to the use of sand on the ground that the natural peat soil produces cranberries of better quality. Again, as previously stated, gravelly sand, such as is used on Cape Cod, is not available in the moorland region of Wisconsin, and ordinary fine sand packs too closely and permits a rank growth of vegetation. The Wisconsin grower states that he can secure better returns financially by using his money in extending his marsh rather than in sanding it, because there are vast areas in Wisconsin available for cranberry culture as compared with the restricted region of Cape Cod; and that if the vines are planted in sand, the cost of preparing the bog for planting

is doubled, without doubling the returns as a result; but this statement is not accepted by Professor Whitson and his assistants connected with the experiment station at Cranmoor. As a matter of fact, the average yield per acre in Cape Cod is 40 barrels; in New Jersey, 30 barrels; and in Wisconsin, only 20 barrels. There are even authentic reports of 200 barrels per acre raised on Cape Cod under most favorable circumstances. It is not denied, however, that sanding is valuable in warding of frost, and the fact that reflowing is seldom required at the experiment station where intensive farming is practiced is, of itself, of the greatest importance. Sanding is obviously needed far more in Wisconsin than in Massachusetts, because the temperature averages much lower in Wisconsin, as has been shown in the introduction of this bulletin. If sanding had been practiced generally in Wisconsin, much of the crop that was destroyed by the frosts in September, 1909, through lack of water for reflowing, would have been saved. The estimated damage, as a result of the frosts of September 1 and 2, 1909, alone, to the entire Wisconsin crop was 50 per cent, while the loss at the Cranmoor Experiment Station was only 2 per cent. Moreover, only about 25 per cent of the crop was eventually saved because of the numerous severe frosts later in the month, to which reference has already been made.

The sanding is usually done during the winter, when the flood covers the marsh. The sand is spread over the ice and it gradually sinks to the surface of the bog in the spring as the ice melts.[a] Cape Cod growers generally sand every few years, adding a layer of about half an inch in thickness, but in Wisconsin no regular custom has been followed. While the greater portion of the Appleton marsh at Mather had been sanded to a depth of about 2 inches in 1898, no further sanding was done until the winter of 1905–6, when a portion of the marsh previously sanded was covered with another layer. Weeding or cultivating has been practiced to a considerable extent, but the growth of vegetation is so rank in many of the bogs that much work is required in order to make any showing. The drainage is steadily being improved, the ditches have been placed closer together and are usually kept clean so as to assist in draining as well as in rapid reflowing.

A study of the general and local conditions necessary for frost in the marshes.—The natural conclusion from the data presented is that the study of local conditions in the marshes is of much importance. It is apparent that the temperature varies greatly in adjoining bogs and even in different portions of the same bog. During a frosty night damage may result in one portion of a bog and not in another, but *serious frosts are usually general and not local.* A grower may wish to conserve the water supply if the season is dry and the water low, because if he makes too liberal use of it, means for reflowing may not be at hand later when great danger threatens. In view of the fact that reflowing should not be resorted to any oftener than is absolutely necessary, the forecaster and the grower have between them a problem to solve that is sometimes very difficult. When low temperature threatens it must be first determined whether the night is to be clear, the barometer high, and the wind light. Of greatest importance is the clearness of the atmosphere, as there will be no decided fall in temperature during any night unless the clouds clear away; even passing clouds over a marsh often raise the temperature several degrees. But local conditions seldom determine the condition of the sky. The reasons for cloudiness must be found in the movement of the areas of high and low pressure; and these reasons are not always apparent on the face of the weather map. The work of forecasting frost for the cranberry marshes is important and requires constant vigilance. True it is that damaging frosts seldom occur in midsummer. The frost of August 7–8, 1904, was abnormal—in fact, a phenomenal condition. The forecaster should know that such a low temperature is not likely to happen in every July or August, because it is far from being the fact, and it can only occur under circumstances on every side favoring its development. It is therefore a well-marked condition—one that would attract the attention of the forecaster almost instantly as he scans the weather map. *Ordinarily, areas of high barometer do not bring frosts to the cranberry marshes of Wisconsin in the midsummer months, even though they are of considerable magnitude, have comparatively low temperature, and move across the northern tier of states.*

[a] In Massachusetts the sanding is now done mostly in the autumn, before the winter flow has been turned on.

The temperature of the soil is usually too high during the warm season to permit the formation of frost, and it is quite impossible for it to occur during these months following a day of sunshine. On the other hand, frost occurs easily in the moorlands on clear nights during the spring, early summer, and autumn when the soil is cold. As stated before, the conditions such as obtained during June 11, 12, and 13, 1906, would not be sufficient to cause frost later in the summer after the ground had become warm. In determining whether frost warnings should be issued, not only the weather maps must be studied carefully, but also the temperature conditions in the bogs produced by recent hot or cold spells. The temperature of the soil is an important factor at any period of the growing season, and the reading of the maximum thermometer is of much value, indicating, as it does, in a measure, the amount of heat conveyed to the soil during the daytime. *Should the maximum temperature in the shelter be below 70° on any day, and be followed at night by clear sky and light wind, barometer above normal and rising, there is strong probability that frost will follow in the bogs, especially if the pressure reaches a height of 30.20 inches or more and the center of the HIGH passes over Wisconsin or the Lake Superior region.* The theory that frost does not follow rain has no foundation. In fact, a day of light rain accompanied by a fresh wind which facilitates evaporation at the surface of the soil is often followed by a frosty night, as evidenced by numerous instances in 1907. (See Table 22.)

Should it be expected that the minimum temperature at La Crosse or St. Paul will fall below 50°, ordinarily there is danger of damage in the cranberry marshes on any clear night. Severe frosts have occurred in the bogs when the temperature at La Crosse was no lower than 48°, as on August 8, 1904, previously referred to. The temperature "in the open" at the coldest place in the bog must fall below 29° in order that serious damage may occur. Probably a temperature for several hours "in the open" as low as 29° would be serious, but there are many instances of minimum temperatures of 29°, and even of 28°, when no frost or resulting damage was apparent.

While frost may occur with a pressure not above normal during the spring, early summer, and autumn, this is not possible during the months of July, August, or early September. The barometer over the moorlands during the warm months must attain a height of at least 30.20 inches, so as to permit the cold air to gradually settle over the bog. On July 2, 1907, when the temperature fell to 29° at Mather with the pressure of 30.10 inches, no frost was observed, but it is probable that if the pressure were as high as 30.20 inches, a frost would have occurred. The higher the pressure the heavier the air, and the lighter the wind the more easily the cold air settles toward the ground.

As stated previously, it is important to determine from the weather map whether the weather will be clear over the moorlands because, regardless of how cold it is in the Northwest and how threatening the conditions, there can be no damage done during the growing season if the weather is cloudy at night; but severe frost may occur early in May before the growing season, and in October after the berries have been picked, on cloudy and windy nights, but no damage can then result in the marshes. A perfect condition for frost in the moorlands exists when a high-pressure area from the Northwest moves eastward with the center over Lake Superior, sending cool north winds thence over Wisconsin, or when the HIGH settles directly over the moorlands, following a day, or preferably two, of cloudiness, with some rain and wind, provided the clouds clear away and the wind subsides in the evening as the temperature begins to fall.[a] While the study of local conditions is of value—temperature and its rate of fall, wind direction and velocity, humidity and pressure—these conditions may not, during unsettled conditions, assist materially in determining whether the weather will clear and frost occur before the following morning. A strong, steady rise in pressure is the best local indication for clearing weather, and without this the weather will probably remain cloudy. While a high pressure area moving eastward and southeastward over the Lake region is usually accompanied by clear, cool weather, occasionally the movements of such areas are abnormal and cloudiness persists in the front of the HIGH. A remarkable instance of persistent cloudiness was noted from September

[a] When a HIGH moves rapidly across Wisconsin, the barometer begins to fall and the wind to rise immediately after the passage of the crest. Under such conditions, a falling temperature up to midnight is followed by rising temperature during the balance of the night.

2 to 5, 1905. On three successive days the pressure was high in the Northwest, reaching 30.44 inches at Prince Albert, and accompanied by freezing temperatures. This area moved slowly southeastward, gradually losing force, but nevertheless maintaining low temperatures. On the morning of September 4 the pressure was highest over Manitoba, and frost was general throughout the Dakotas. The weather, however, although cold in the moorlands, never cleared during the entire period. Temperatures were as low as 37° on two successive nights, but by reason of the continued cloudiness frost did not occur in the bogs. A study of the local conditions, aside from the pressure, would not have enabled a person to determine whether it would clear on either of these nights. The cloudy weather covered a considerable area, in fact, several states, and the reason for this condition could not be found in the moorland sections of Wisconsin. Similar instances have been noted in other Septembers. When cloudy weather prevails over a large area in front of a HIGH, it may ordinarily be expected to continue, unless there is a steady increase in pressure between the LOW and the HIGH. In case of doubt, special observations should be called for by the forecaster in the middle of the afternoon from the cranberry marshes and a few stations in the Northwest, with special reference to the maximum temperature in the bogs and the probability of clear weather for the ensuing night. It might be well to have an observation of soil temperature included in the reports from the cranberry marsh stations each morning in addition to the data usually telegraphed.

The maps of August 7 and 8, 1904 (Figs. 4, 5), have been included in this bulletin, illustrating a perfect condition for the occurrence of frost. The cloudy weather during the 6th and 7th had prevented the usual warming of the soil, and the breezy weather of the 7th, through evaporation of the moisture near the surface, evidently caused the soil to become colder. The maximum temperature in the shelter on August 6 was 76° at Mather and Cranmoor, and on August 7 it was 65° at Mather and 67° at Cranmoor. We have already shown what a great effect the temperature of the soil has upon the temperature of the air near the surface during any night, and that in marshes the places covered with dense vegetation, with thick matting of moss or thick growth of vines or ferns, are the ones of lowest temperature, especially if the soil has not been sanded and the drainage is poor. When the soil is largely protected from the sun's heat by vegetation and the initial temperature at the surface is low in the evening, comparatively low minimum temperatures must result if the night be clear. The situation is even more pronounced if the previous day has been cloudy, because, as a consequence, the storing of heat in the soil has been interrupted and the point of critical temperature may therefore be reached more readily. *The relation between the temperature of the soil and the occurrence of frost is noticeable in that it is practically impossible for frost to occur in the bogs on the first cool night following a warm spell, but it is likely, if conditions are favorable, on the second night after the soil has become cold.* Growers claim, and with reason, that frost almost invariably occurs on the second night of a cold spell, and even if it does occur on the first night the frost on the second night is likely to be more severe.

Frost remains in the soil of an unflooded bog until comparatively late in the season, and there have been found instances of frost in the soil in marshes as late as July 4. Usually, however, when the winter flow is taken off in the spring the soil is free from frost. The temperature of the soil tends to gradually increase until after midsummer, and then gradually decrease again. *The soil being cold in the spring and early summer, and again in the fall, frost is more likely to occur then, regardless of the accompanying conditions of atmospheric temperature and pressure. That is, the ground being cold, frost will occur in the marshes in May and early in June under the influence of areas of high pressure and accompanying low temperature that would be far from sufficient to cause frost during the midsummer months, when heat has been stored up in the soil. The length of the nights is also very important in estimating the probability of the occurrence of frost, especially during the months of September and October, as the nights steadily grow longer and afford greater opportunity for radiation, without compensating insolation.*

The forecaster must have in mind the lowest temperature that may occur in the less-favored sections of the marsh, as it is evident that a wide range in temperature will be found in practically all marshes. Even with the knowledge that the lowest temperature "in the

open" will fall below the freezing point, it is not certain that there will be any damage. In fact, as has been stated before, the result of the investigation indicates that the temperature "in the open" must fall 2° to 4° below the freezing point in order to cause any serious damage. But the forecaster need not be the judge of what damage may ensue. It is for him to issue warnings, stating in his forecast the probability of light, heavy, or killing frost, and, if possible, how long the cool condition is likely to last; because such information will often assist the cranberry grower in conserving his water supply. It is very important to know the hour in the evening that the frost is likely to set in, because if it begins to form before midnight the damage to unprotected marshes is certain to be serious, as the period of freezing in that event will continue through several hours till daybreak. When, however, the frost does not begin to form until nearly dawn there is little probability of damage. For traces of the curves at Berlin during the nights of September 13–14 and 27–28, 1906, see Figure 31, showing first in one instance a fall to freezing for only a brief period and in the other the temperature remaining at a low point for several hours.

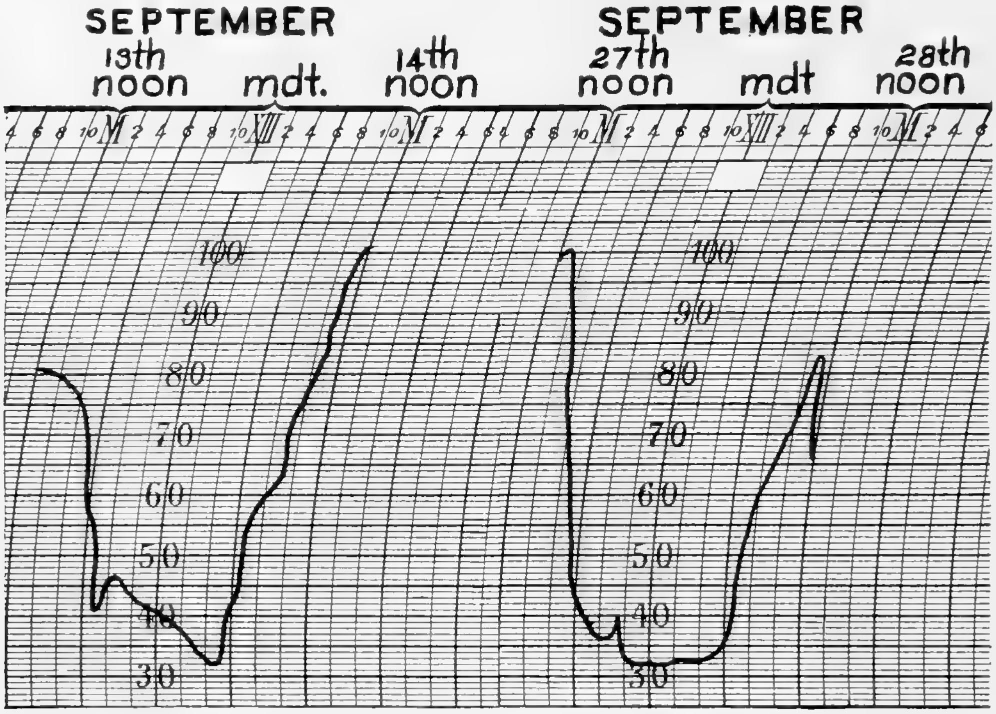

FIG. 31.—Berlin, Wis., 1906.

Temperature curves in the vines on the marsh. Examples of two days—first, when minimum temperature touched freezing point for a few minutes—second, when the temperature remained at freezing for several hours. Irregularity of curves in both cases due to wind or passing clouds.

There is an opportunity for the forecaster to give great assistance to the cranberry grower and to place in the hands of the latter all the information that may be available. If possible, it is advisable to send advice twenty-four hours or more in advance at times when the growers have the water supply low in the ditches, as is customary in the summer time, in order to enable them to raise the water, thus permitting easy flooding on the ensuing day. With this assistance the most improved marsh can then be flooded in a brief period. Many growers state that they want advice even when *frost is possible, as well as probable*, so that they may never be found entirely unprepared. If the water is allowed to get very low in the ditches, it may take twelve hours or more to flood, as the dry, spongy bog absorbs an immense amount of water. The grower, having been properly informed, can act accordingly, taking into consideration the probable conditions, the amount of his available water supply, and the possible damage, should he not reflow his marsh. When the water is warm during the summer season, and a light frost is expected, danger can usually be averted by raising the water no higher than the surface of

the marsh; yet such flooding affords but little protection should a severe freeze occur. The grower is well acquainted with the conditions of the vines and the fruit, and knows from experience when they are most liable to damage. He understands that at certain times during the season the marsh is practically immune to damage. For instance, after the winter flow is taken off in the spring and before the terminal buds have swollen and begun to burst there is little danger of damage, but later the liability is very great. The winter flow is held on some marshes later than others, but when it is drawn off after May 15 the buds usually begin to swell five to ten days later. After the upright starts out from the terminal bud it is very tender, and there is more danger to it than to the fruit bud, as it will freeze more easily. The fruit blossoms usually appear at Mather about June 10 and the vines are in full bloom about July 1. The setting of the fruit begins with the falling of the first blossoms and continues until the vines are out of blossom. The new terminal bud is generally formed by August 10, and often before that date. During 1906 there were many terminal buds fully formed by August 5. Until the terminal bud is well formed and protected a frost may destroy it, and thus ruin the prospects of a crop for the ensuing year, aside from the damage to the crop of the current year. The terminal bud, however, is free from damage by frost usually after September 1. The fruit itself will freeze most easily just after setting, on account of the large amount of water it contains, and the riper the berry becomes the more hardy it is, so that when it is fully matured *it can not be damaged except by a severe frost.* Information of this character is of importance to the forecaster, simply because it indicates that the frost warnings have more value at one time of the year than another; that a frost in July or early in August, for instance, may wipe out not only the crop of the current year but even the prospects for a crop a year later. As an actual result of the freeze of August 8, 1904, the crop of that year in the Wisconsin River Valley was reduced about 40 per cent and that of 1905 about 25 per cent.

It is possible for the forecaster to acquire a high degree of accuracy in special work of this character. He should never fail to issue warnings previous to serious frosts, and he seldom should make the mistake of issuing warnings for frosts that do not occur, but he should realize that it is his duty to save the crop. It is not enough for him to issue warnings in advance of ten frosts of which the growers take advantage in protecting their marshes, and yet fail to send a warning in advance of the eleventh frost, which results in great injury. *He should realize that he must carry on this work to a successful conclusion from the beginning to the end of the season, or, in other words, that he must "save the crop."* He may sometimes be excused for issuing warnings that are not verified, especially if there is ample water supply for protection; but he will never be excused for failure to issue warnings in advance of serious damage.

O

W. B. No. 443. Issued Dec. 31, 1910.

U. S. DEPARTMENT OF AGRICULTURE,

WEATHER BUREAU.

BULLETIN T.

FROST AND TEMPERATURE CONDITIONS IN THE CRANBERRY MARSHES OF WISCONSIN.

Prepared under the direction of WILLIS L. MOORE, Chief of Weather Bureau,

By

HENRY J. COX, Professor of Meteorology.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1910.